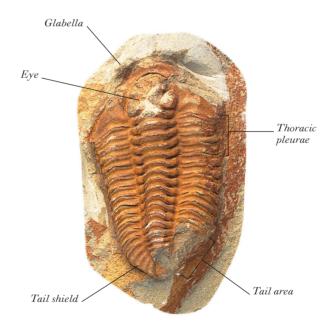
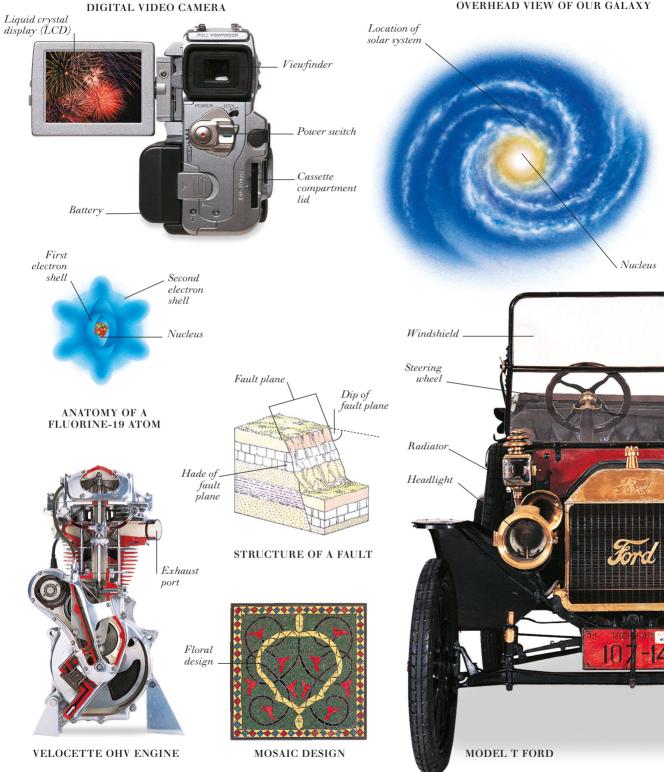


ULTIMATE WISUAL dictionary



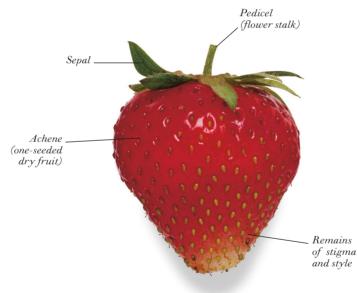
PREHISTORIC TRILOBITE

OVERHEAD VIEW OF OUR GALAXY



ULTIMATE VISUAL

dictionary



STRAWBERRY







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EXTERNAL FEATURES OF A SPIDER



FOUNTAIN PEN AND INK



SONY AIBO ROBOT DOG



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gear

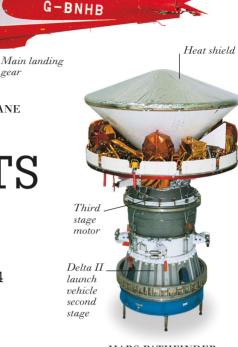
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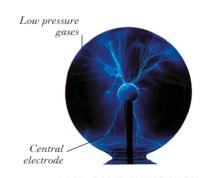
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Fin

MARS PATHFINDER



BALL CONTAINING HIGH TEMPERATURE GAS (PLASMA)



FOOTBALL HELMET

Introduction

THE VISUAL DICTIONARY is a completely new kind of reference book. It provides a link between pictures and words in a way that no ordinary dictionary ever has. Most dictionaries simply tell you what a word means, but the VISUAL DICTIONARY shows you—through a combination of detailed annotations. explicit photographs, and illustrations. In the VISUAL DICTIONARY, pictures define the annotations around them. You do not read definitions of the annotated words. you see them. The highly accessible format of the VISUAL DICTIONARY, the thoroughness of its annotations, and the range of its subject matter make it a unique and helpful reference tool.

How to use the VISUAL DICTIONARY

You will find the Visual Dictionary simple to use. Instead of being organized alphabetically, it is divided by subject into 14 sections—The Universe, Prehistoric Earth, Plants, Animals, The Human Body, etc. Each section begins with a table of contents listing the major entries within that section. For example, The Visual Arts section has entries on Drawing, Tempera, Fresco, Oils, Watercolor, Pastels, Acrylics, Calligraphy, Printmaking, Mosaic, and Sculpture. Every entry has a short introduction explaining the purpose of the photographs and illustrations, and the significance of the annotations.

If you know what something looks like, but don't know its name, find the term you need by turning to the annotations surrounding the pictures; if you know a word, but don't know what it refers to, use the comprehensive index to direct you to the appropriate page.

Suppose that you want to know what the bone at the end of your little finger is called. With a standard dictionary, you wouldn't know where to begin. But with the <code>VISUAL DICTIONARY</code> you simply turn to the entry called <code>Hands</code>—within The Human Body section—where you will find four fully

annotated, color photographs showing the skin, muscles, and bones of the human hand. In this entry you will quickly find that the bone you are searching for is called the distal phalanx, and for good measure you will discover that it is attached to the middle phalanx by the distal interphalangeal joint.

Perhaps you want to know what a catalytic converter looks like. If you look up "catalytic converter" in an ordinary dictionary, you will be told what it is and possibly what it does—but you will not be able to tell what shape it is or what it is made of. However, if you look up "catalytic converter" in the index of the Visual Dictionary, you will be directed to the Modern engines entry on page 344—where the introduction gives you basic information about what a catalytic converter is—and to page 350—where there is a spectacular exploded-view photograph of the mechanics of a Renault Clio. From these pages you will find out not only what a catalytic converter looks like, but also that it is attached at one end to an exhaust pipe and at the other to a muffler.

Whatever it is that you want to find a name for, or whatever name you want to find a picture for, you will find it quickly and easily in the *VISUAL DICTIONARY*. Perhaps you need to know where the vamp on a shoe is; or how to tell obovate and lanceolate leaves apart; or what a spiral galaxy looks like; or whether birds have nostrils. With the *VISUAL DICTIONARY* at hand, the answers to each of these questions, and thousands more, are readily available.

The Visual Dictionary does not just tell you what the names of the different parts of an object are. The photographs, illustrations, and annotations are all specially arranged to help you understand which parts relate to one another and how objects function.

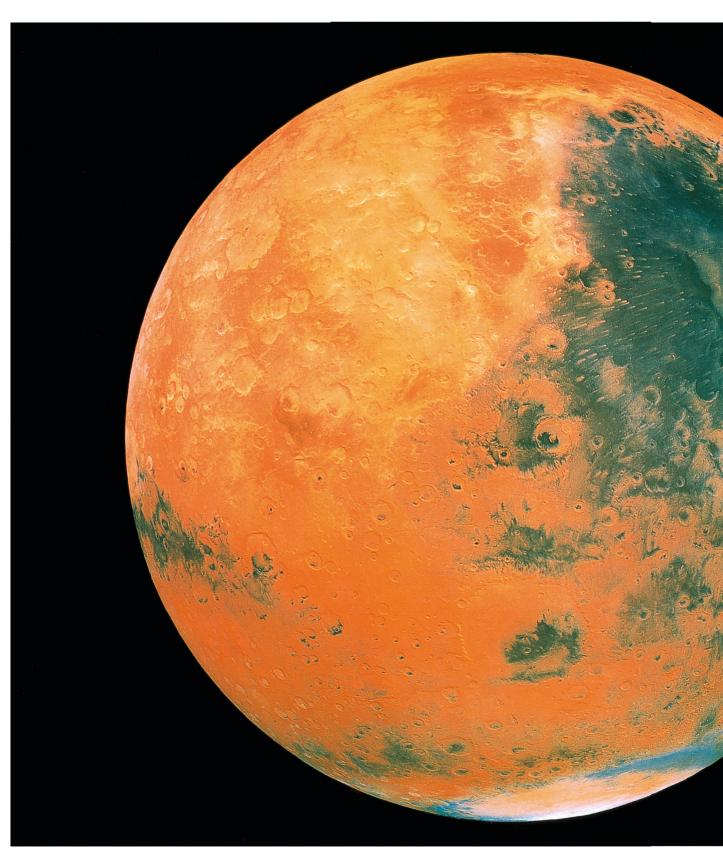
With the Visual Dictionary you can find in seconds the words or pictures that you are looking for; or you can simply browse through the pages of the book for your own pleasure. The Visual Dictionary is not intended to replace a standard dictionary or conventional encyclopedia, but is instead a stimulating and valuable companion to ordinary reference volumes. Giving you instant access to the language that is used by astronomers and architects, musicians and mechanics, scientists and sportspeople, it is the ideal reference book for specialists and generalists of all ages.

Sections of the VISUAL DICTIONARY

The 14 sections of the *VISUAL DICTIONARY* contain a total of more than 30,000 terms, encompassing a wide range of topics:

- In the first section, The Universe, spectacular photographs and illustrations are used to show the names of the stars and planets and to explain the structure of solar systems, galaxies, nebulae, comets, and black holes.
- PREHISTORIC EARTH tells the story in annotations of how our own planet has evolved since its formation. It includes examples of prehistoric flora and fauna, and fascinating dinosaur models—some with parts of the body stripped away to show anatomical sections.
- •PLANTS covers a huge range of species—from the familiar to the exotic. In addition to the color photographs of plants included in this section, there is a series of micrographic photographs illustrating plant details—such as pollen grains, spores, and cross-sections of stems and roots—in close-up.
- •In the ANIMALS section, skeletons, anatomical diagrams, and different parts of animals' bodies have been meticulously annotated. This section provides a comprehensive guide to the vocabulary of zoological classification and animal physiology.
- •The structure of the human body, its parts, and its systems are presented in THE HUMAN BODY. The section includes lifelike, three-dimensional models and the latest false-color images. Clear and authoritative annotations indicate the correct anatomical terms.
- •GEOLOGY, GEOGRAPHY, AND METEOROLOGY describes the structure of the Earth—from the inner core to the exosphere—and the physical phenomena—such as volcanoes, rivers, glaciers, and climate—that shape its surface.

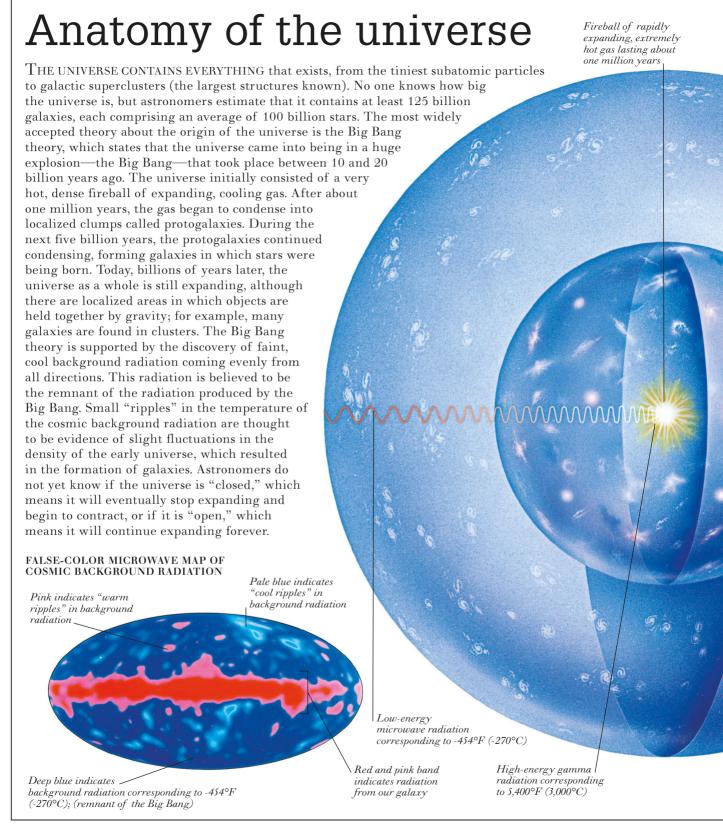
- PHYSICS AND CHEMISTRY is a visual journey through the fundamental principles underlying the physical universe, and provides the essential vocabulary of these sciences.
- •In RAIL AND ROAD, a wide range of trains, trams and buses, cars, bicycles, and motorcycles are described. Exploded-view photographs show mechanical details with striking clarity.
- •SEA AND AIR gives the names for hundreds of parts of ships and airplanes. The section includes civil and fighting craft, both historical and modern.
- THE VISUAL ARTS shows the equipment and materials used by painters, sculptors, printers, and other artists. Well-known compositions have been chosen to illustrate specific artistic techniques and effects.
- •ARCHITECTURE includes photographs of exemplary architectural models and illustrates dozens of additional features such as columns, domes, and arches.
- •MUSIC provides a visual introduction to the special language of music and musical instruments. It includes clearly annotated photographs of each of the major groups of traditional instruments—brass, woodwind, strings, and percussion—together with modern electronic instruments.
- The SPORTS section is a guide to the playing areas, formations, equipment, and techniques needed for many of today's most popular sports.
- In THE MODERN WORLD, items that are a familiar part of our daily lives are taken apart to reveal their inner workings and give access to the language used by their manufacturers. It also includes systems and concepts, such as the internet, that increasingly influence our 21st century world.





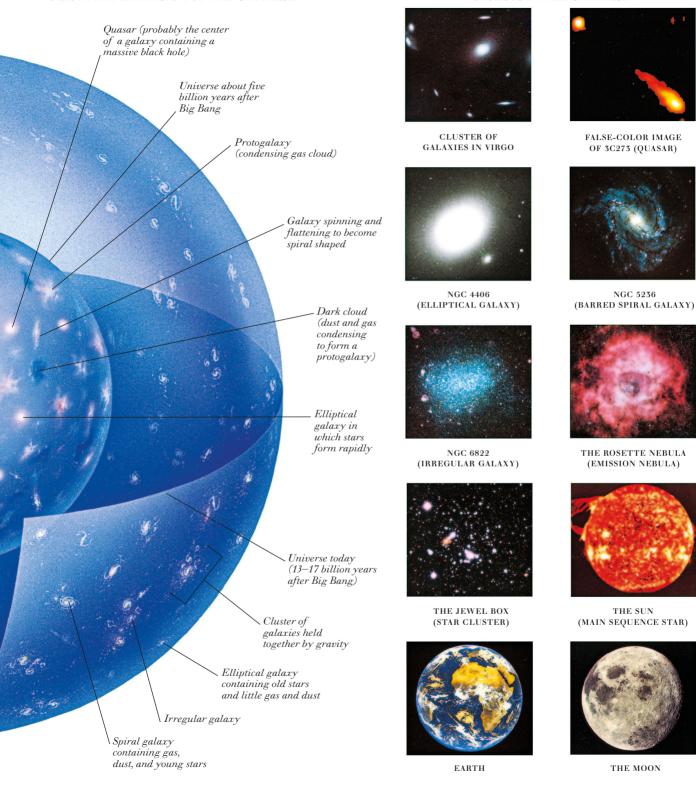
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ORIGIN AND EXPANSION OF THE UNIVERSE

OBJECTS IN THE UNIVERSE



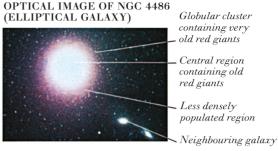
Galaxies



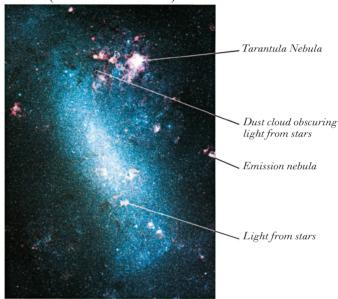
SOMBRERO, A SPIRAL GALAXY

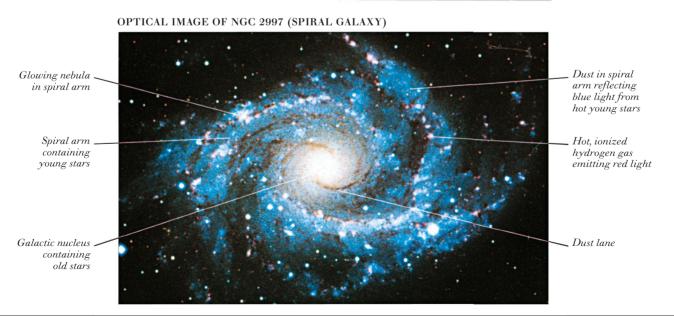
A GALAXY IS A HUGE MASS OF STARS, nebulae, and interstellar material. The smallest galaxies contain about 100,000 stars, while the largest contain up to 3 trillion stars. There are three main types of galaxy, classified according to their shape: elliptical, which are oval shaped; spiral,

which have arms spiraling outward from a central bulge (those whose arms spiral from a bar-shaped bulge are called spirals); and irregular, which have no obvious shape. Sometimes, the shape of a galaxy is distorted by a collision with another galaxy. Quasars (quasistellar objects) are thought to be galactic nuclei but are so far away that their exact nature is still uncertain. They are compact, highly luminous objects in the outer reaches of the known universe: while the farthest known "ordinary" galaxies are about 12 billion light-years away, the farthest known quasar is about 13 billion lightyears away. Active galaxies, such as Seyfert galaxies and radio galaxies, emit intense radiation. In a Seyfert galaxy, this radiation comes from the galactic nucleus; in a radio galaxy, it also comes from huge lobes on either side of the galaxy. The radiation from active galaxies and quasars is thought to be caused by material falling into central black holes (see pp. 28-29).

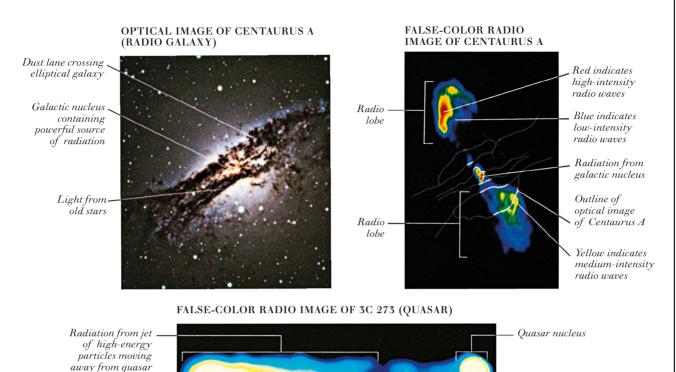


OPTICAL IMAGE OF LARGE MAGELLANIC CLOUD (IRREGULAR GALAXY)

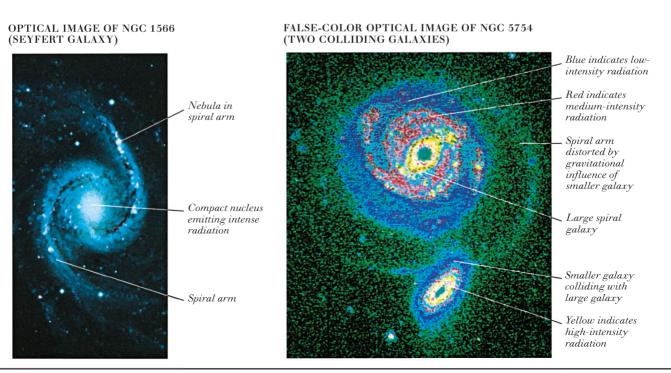




White indicates highintensity radio waves



Blue indicates low-intensity radio waves



The Milky Way



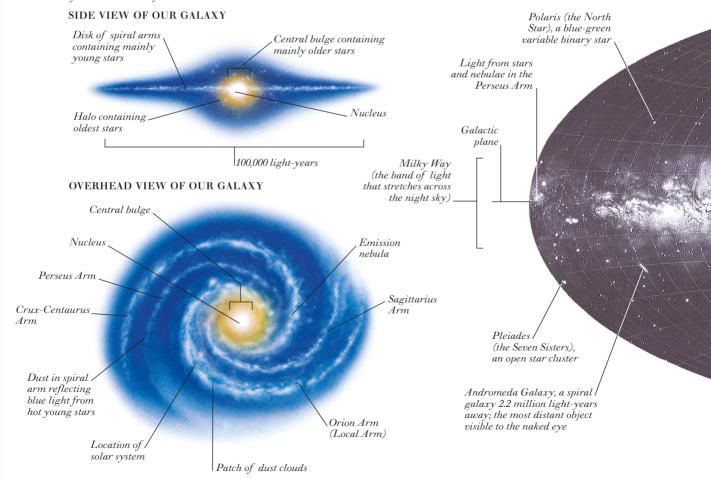
VIEW TOWARD
GALACTIC CENTER

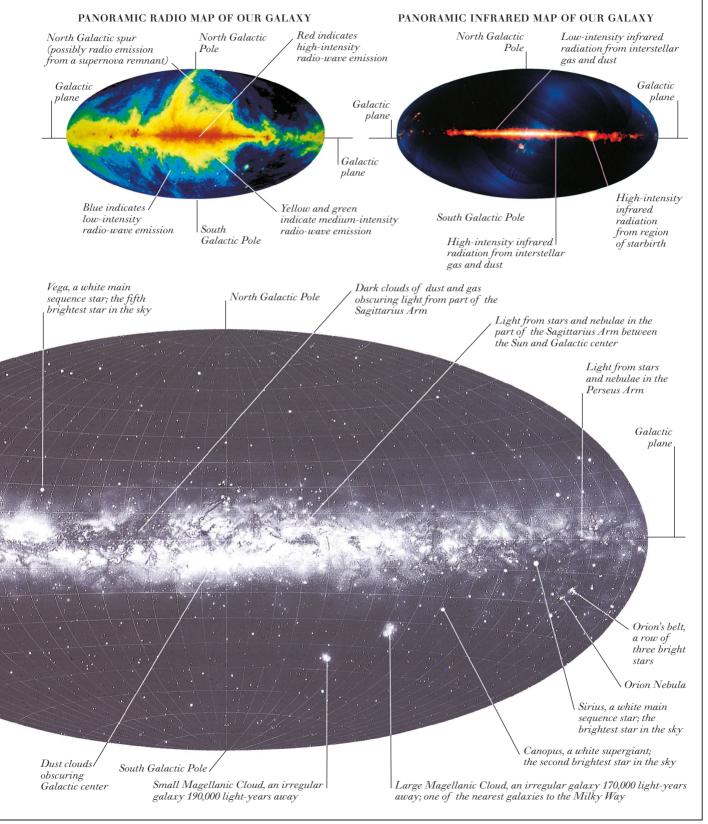
The Milky way is the Name Given to the faint band of light that stretches across the night sky. This light comes from stars and nebulae in our galaxy, known as the Milky Way Galaxy or simply as "the Galaxy." The Galaxy is believed to be a barred spiral, with a dense central bar of stars encircled by four arms spiraling outward and surrounded by a less dense halo. We cannot see the spiral shape because the solar system is in one of the spiral arms, the Orion Arm (also called the Local Arm). From our position, the center of the Galaxy is completely obscured by dust clouds; as a result, optical maps give only a limited view of the Galaxy. However, a more complete picture can be

obtained by studying radio, infrared, and other radiation. The central part of the Galaxy is relatively small and dense and contains mainly older red and yellow stars. The halo is a less dense region in which the oldest stars are situated; some of these stars are as old as the Galaxy itself (possibly 13 billion years). The spiral arms contain main sequence stars and hot, young, blue stars, as well as nebulae (clouds of dust and gas inside which stars are born). The Galaxy is vast, about 100,000 light-years across (a light-year is about 5,870 billion miles/9,460 billion km); in comparison, the solar system seems small, at about 12 light-hours across (about 8 billion miles/13 billion km). The entire Galaxy is rotating in space, although the inner stars travel faster than those farther out. The Sun, which is

about two-thirds out from the center, completes one lap of the Galaxy about every 220 million years.

PANORAMIC OPTICAL MAP OF OUR GALAXY AND NEARBY GALAXIES





Nebulae and star clusters



HODGE 11. A GLOBULAR CLUSTER

 ${
m A}$ NEBULA IS A CLOUD OF DUST AND GAS inside a galaxy. Nebulae become visible if the gas glows, or if the cloud reflects starlight or obscures light from more distant objects. Emission nebulae shine because their gas emits light when it is stimulated by radiation from hot young stars. Reflection nebulae shine because their dust reflects light from stars in or around the nebula. Dark nebulae appear as silhouettes because they block out light from shining nebulae or stars behind them. Two types of nebula are associated with dying stars: planetary nebulae and supernova remnants. Both consist of expanding shells of gas that were once the outer layers of a star. A planetary nebula is a gas shell drifting away

Emission

Dust lane

Starbirth region

(area in which

clump together

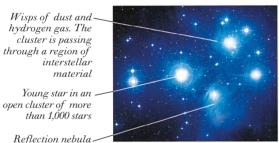
to form stars)

dust and gas

nebula

from a dving stellar core. A supernova remnant is a gas shell moving away from a stellar core at great speed following a violent explosion called a supernova (see pp. 26-27). Stars are often found in groups known as clusters. Open clusters are loose groups of a few thousand young stars that were born from the same cloud and are drifting apart. Globular clusters are densely packed, roughly spherical groups of hundreds of thousands of older stars.

PLEIADES (OPEN STAR CLUSTER) WITH A REFLECTION NEBULA



Reflection nebula

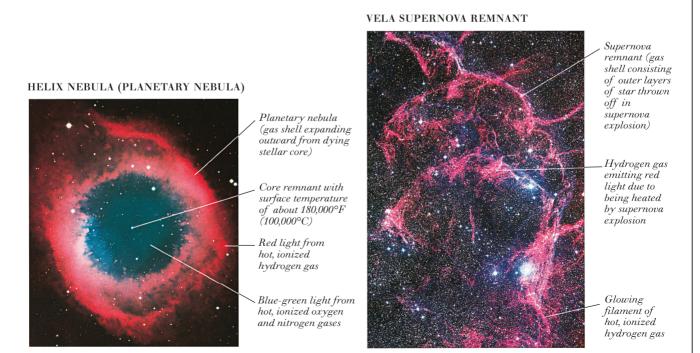
TRIFID NEBULA (EMISSION NEBULA)

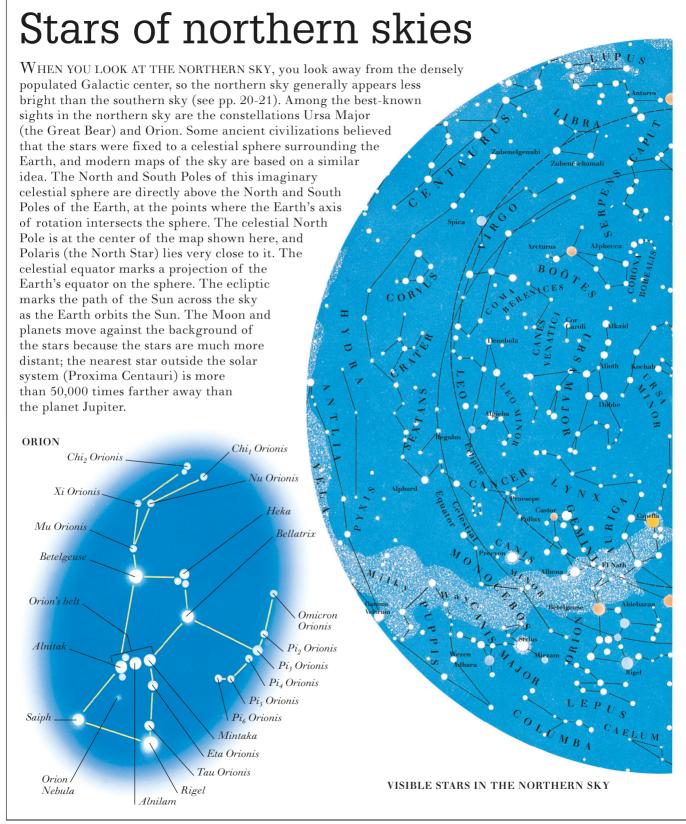


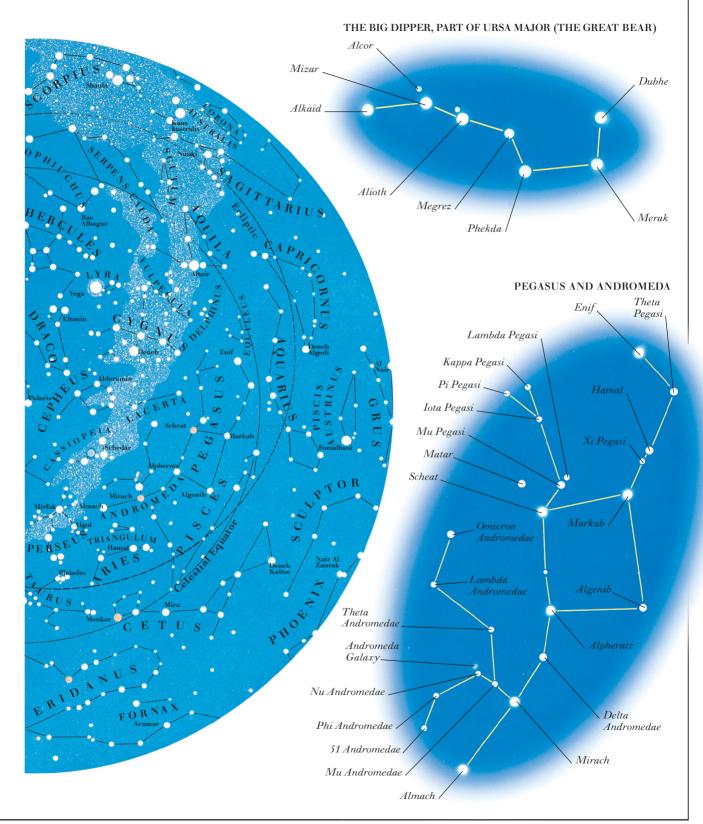
HORSEHEAD NEBULA (DARK NEBULA)

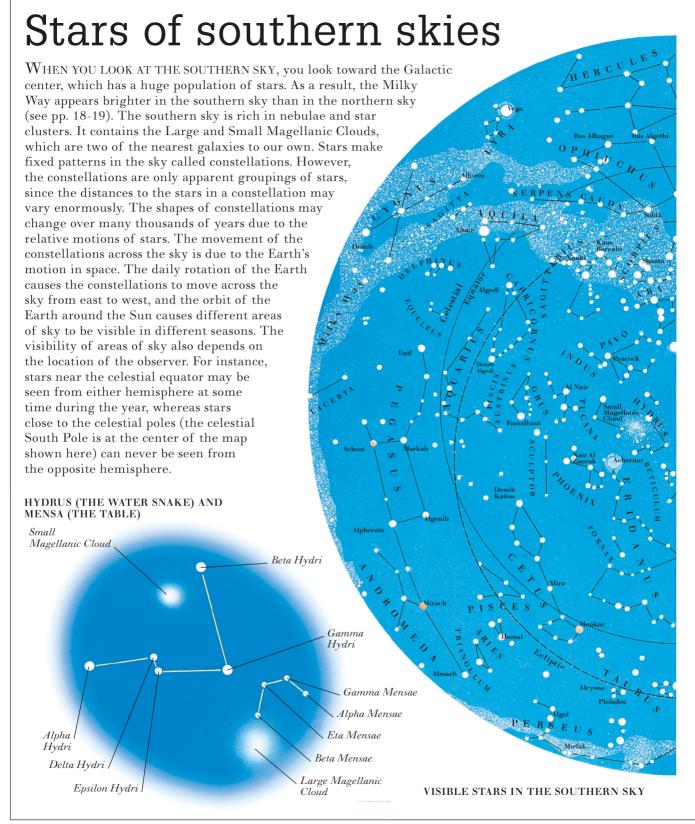


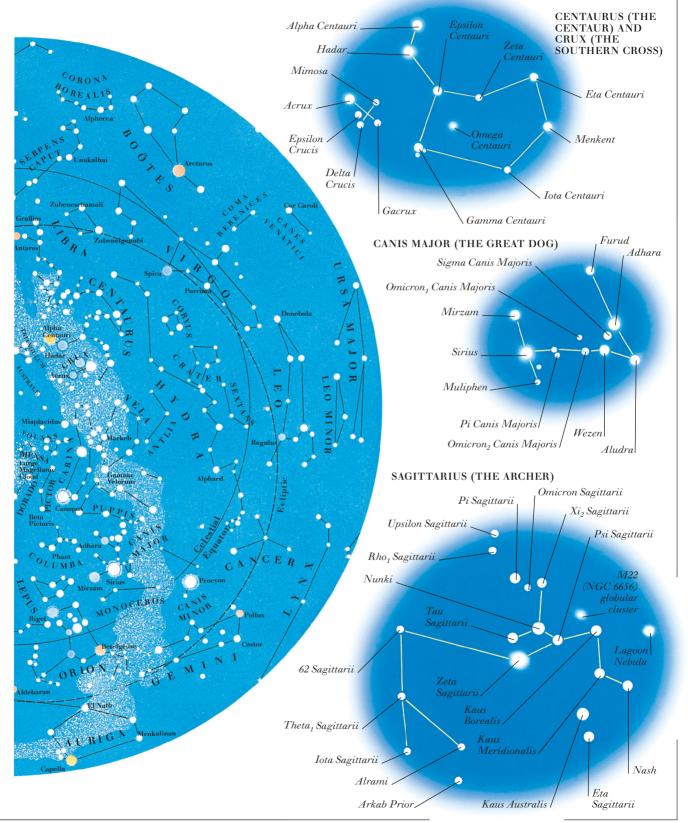
ORION NEBULA (DIFFUSE EMISSION NEBULA) Glowing Gas cloud cloud of dust emitting and hydrogen light due to gas forming ultravioletpart of Orion radiation from the four young Trapezium stars Nebula Dust cloud . Trapezium(group of four young stars) Green light from hot, ionized oxygen gas Glowing filament of Red light hot, ionized from hot, hydrogen gas ionized hydrogen gas











Stars



OPEN STAR CLUSTER AND DUST CLOUD

STARS ARE BODIES of hot, glowing gas that are born in nebulae (see pp. 24-27). They
vary enormously in size, mass, and temperature: diameters range from about 450 times smaller to over 1,000 times bigger than that of the Sun; masses range from about a twentieth to over 50 solar masses; and surface temperatures range from about 5,500°F

 $(3,000^{\circ}\text{C})$ to over $90,000^{\circ}\text{F}$ $(50,000^{\circ}\text{C})$. The color of a star is determined by its temperature: the hottest stars are blue and the coolest are red. The Sun, with a surface temperature of $10,000^{\circ}\text{F}$ $(5,500^{\circ}\text{C})$, is

between these extremes and appears yellow. The energy emitted by a shining star is usually produced by nuclear fusion in the star's core. The brightness of a star is measured in magnitudes—the brighter the star, the lower its magnitude. There are two types of magnitude: apparent magnitude, which is the brightness seen from Earth, and absolute magnitude, which is the brightness that would be seen from a standard distance of 10 parsecs (32.6 light-years). The light emitted by a star may be split to form a spectrum containing a series of dark lines (absorption lines). The patterns of lines indicate the presence of particular chemical elements, enabling astronomers to deduce the composition of the star's atmosphere. The magnitude and spectral type (color) of stars may be plotted on a graph called a Hertzsprung-Russell diagram, which shows that stars tend to fall into several well-defined groups. The principal groups are main sequence stars (those which are fusing hydrogen to form helium), giants, supergiants, and white dwarfs.

STAR SIZES

Red giant from 10 to 100 million miles (15 to 150 million km) wide

The Sun (main sequence star; diameter 870,000 miles/1.4 million km)

White dwarf (diameter of 2,000 to 30,000 miles/3,000 to 50,000 km)

ENERGY EMISSION FROM THE SUN

Nuclear fusion in core produces gamma rays and neutrinos

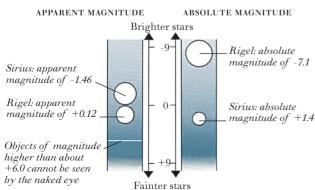
Lower-energy radiation travels to Earth in about 8 minutes

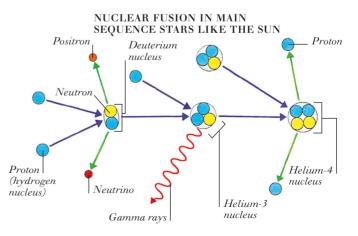
Earth

Lower-energy radiation (mainly ultraviolet, infrared, and light rays) leaves surface

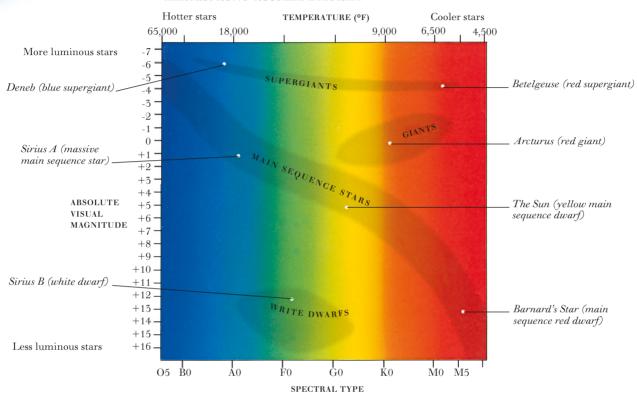
High-energy radiation | (gamma rays) loses energy while traveling to surface over 2 million years

STAR MAGNITUDES

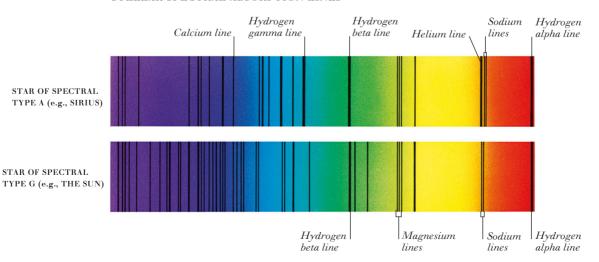




HERTZSPRUNG-RUSSELL DIAGRAM



STELLAR SPECTRAL ABSORPTION LINES



Small stars



REGION OF STAR FORMATION IN ORION

SMALL STARS HAVE A MASS of up to about one and a half times that of the Sun. They begin to form when a region of higher density in a nebula condenses into a huge globule of gas and dust that contracts under its own gravity. Within a globule, regions of condensing matter heat up and begin to glow, forming protostars. If a protostar contains enough matter, the central temperature reaches about 27 million °F (8 million °C). At this temperature, nuclear reactions in which hydrogen fuses to form helium can start. This process releases energy, which prevents the star from contracting more and also causes it to shine; it is now a main sequence star. A star of about one solar mass remains

on the main sequence for about 10 billion years, until much of the hydrogen in

the star's core has been converted into helium. The helium core then contracts. and nuclear reactions continue in a shell around the core. The core becomes hot enough for helium to fuse to form carbon, while the outer layers of the star expand and cool. The expanding star is known as a red giant. When the helium in the core runs out, the outer

layers of the star may be blown away as an expanding gas shell called a planetary nebula. The remaining core (about 80 percent of the original star) is now in its final stages. It becomes a white dwarf star that gradually cools and dims. When it finally stops shining altogether, the dead star will become a black dwarf.

MAIN SEQUENCE STAR Core containing hydrogen fusing to form helium Radiative 70ne zone

STRUCTURE OF A

Convective Surface temperature 10,000°F (5,500°C) Core: 27 million ${}^{\circ}F$ (15 million °C)

STRUCTURE OF A NEBULA

sequence star Dense region of dust and

to form globules

gas (mainly hydrogen)

condensing under gravity

Young main

Hot, ionized hydrogen gas emitting red light due to being stimulated by radiation from hot young stars

Dark globule of dust and gas (mainly hydrogen) contracting to form protostars

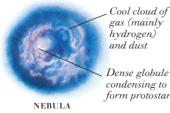
Natal cocoon

(shell of dust

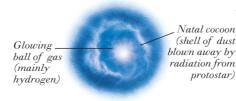
radiation from

protostar)

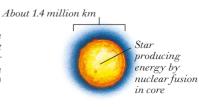
LIFE OF A SMALL STAR OF ABOUT ONE SOLAR MASS



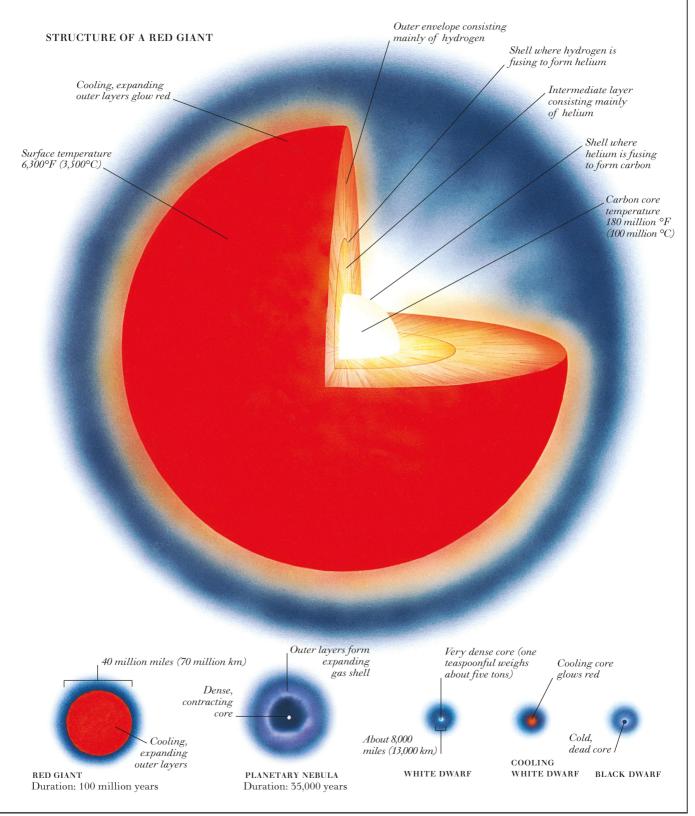
hydrogen) and dust Dense globule condensing to form protostars



PROTOSTAR Duration: 50 million years



MAIN SEQUENCE STAR Duration: 10 billion years



Massive stars

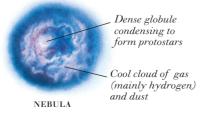
MASSIVE STARS HAVE A MASS AT LEAST THREE TIMES that of the Sun, and some stars are as massive as about 50 Suns. A massive star evolves in a similar way to a small star until it reaches the main sequence stage (see pp. 24-25). During its life as a main sequence star, it shines steadily until the hydrogen in its core has fused to form helium. This process takes billions of years in a small star, but only millions of years in a massive star. A massive star then becomes a red supergiant, which initially consists of a helium core surrounded by outer layers of cooling, expanding gas. Over the next few million years, a series of nuclear reactions form different elements in shells around an iron core. The core eventually collapses in less than a second, causing a massive explosion called a supernova, in which a shock wave blows away the outer layers of the star. Outer envelope consisting mainly of hydrogen

Supernovae shine brighter than an entire galaxy for a short time. Sometimes, the core survives the supernova explosion. If the surviving core is between about one and a half and three solar masses, it contracts to become a tiny, dense neutron star. If the core is greater than three solar masses. it contracts to become a black hole

(see pp. 28-29).

Surface temperature 5,500°F (3,000°C) Cooling, expanding outer layers glow red . Core of mainly iron at 5.4-9, billion °F (3-5 billion °C)

LIFE OF A MASSIVE STAR OF ABOUT 10 SOLAR MASSES



SUPERNOVA



TARANTULA NEBULA BEFORE SUPERNOVA

STRUCTURE OF A RED SUPERGIANT

Layer consisting mainly of helium Layer consisting mainly of carbon

> Laver consisting mainly of oxygen

Layer consisting mainly of silicon

fusing to form helium Shell of helium

> fusing to form carbon

Shell of hydrogen

Shell of carbon fusing to form

oxygen Shell of oxygen fusing to form silicon

Shell of silicon fusing to form iron core

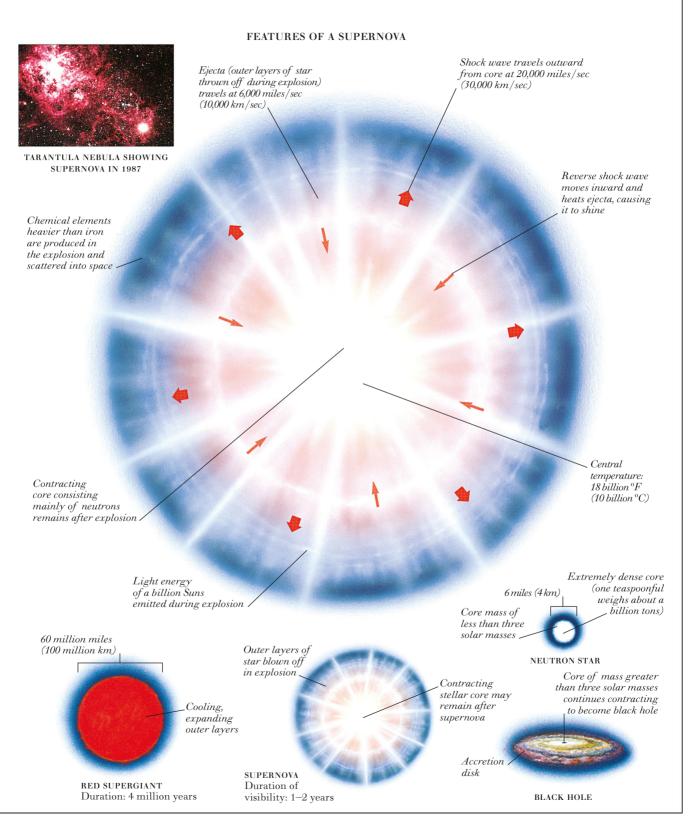
About 2 million Glowing ball of gas (mainly hydrogen) Natal cocoon (shell of dust blown away by radiation from

protostar)

PROTOSTAR Duration: a few hundred thousand years

Star producing energy by nuclear miles (3 million km) fusion in core

> MAIN SEQUENCE STAR Duration: 10 million years



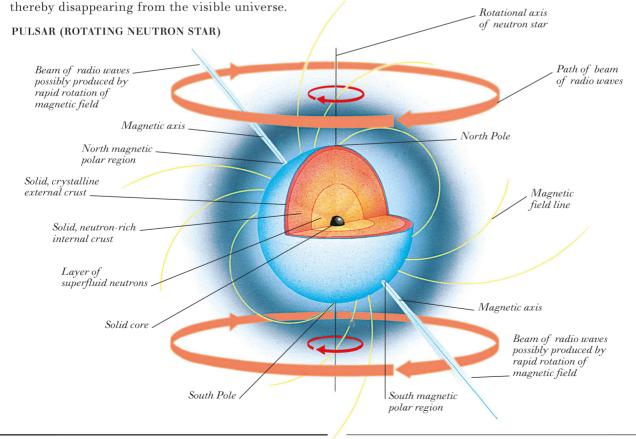
Neutron stars and black holes

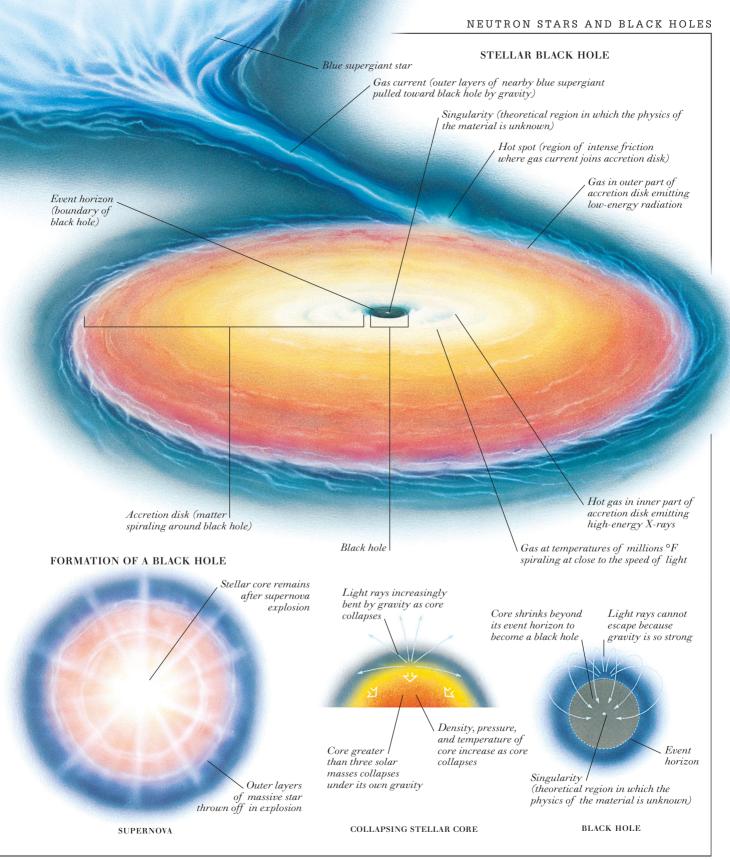
NEUTRON STARS AND BLACK HOLES form from the stellar cores that remain after stars have exploded as supernovae (see pp. 26-27). If the remaining core is between about one and a half and three solar masses, it contracts to form a neutron star. If the remaining core is greater than about three solar masses, it contracts to form a black hole. Neutron stars are typically only about 6 miles (10 km) in diameter and consist almost entirely of subatomic particles called neutrons. Such stars are so dense that a teaspoonful would weigh about a billion tons. Neutron stars are observed as pulsars, so-called because they rotate rapidly and emit two beams of radio waves, which sweep across the sky and are detected as short pulses. Black holes are characterized by their extremely strong gravity, which is so powerful that not even light can escape; as a result, black holes are invisible. However, they can be detected if they have a close companion star. The gravity of the black hole pulls gas from the other star, forming an accretion disk that spirals around the black hole at high speed, heating up and emitting radiation. Eventually, the matter spirals in to cross the event horizon (the boundary of the black hole),

Nebula of gas and dust surrounds pulsar Rapidly_ rotating pulsar

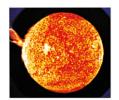
Beam of_ radiation from pulsar

X-RAY IMAGE OF PULSAR AND CENTRAL REGION OF CRAB NEBULA (SUPERNOVA REMNANT)





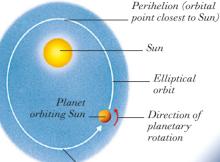
The solar system



THE SOLAR SYSTEM consists of a central star (the Sun) and the bodies that orbit it. These bodies include eight planets and their more than 160 known moons; dwarf planets; Kuiper Belt objects; asteroids; comets; and meteoroids. The solar system also contains interplanetary gas and dust. The planets fall into two groups: four small rocky planets near the Sun (Mercury, Venus, Earth, and

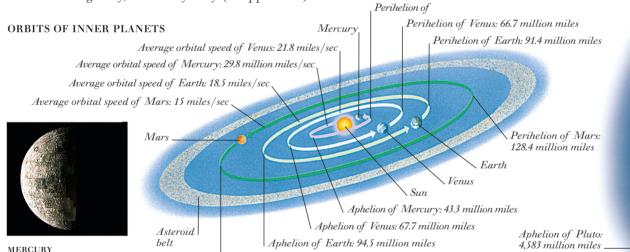
Mars); and four planets farther out, the giants (Jupiter, Saturn, Uranus, and Neptune). Between the rocky planets and giants is the asteroid belt, which contains thousands of chunks of rock orbiting the Sun. Beyond Neptune is the Kuiper Belt and, more distant, the Oort Cloud. Most of the bodies in the planetary part of the solar system move around the Sun in elliptical orbits located in a thin disk around the Sun's equator. All the planets orbit the Sun in the same direction (counterclockwise when viewed from above) and all but Venus and Uranus also spin about their axes in this direction. Moons also spin as they, in turn, orbit their planets. The entire solar system orbits the center of our galaxy, the Milky Way (see pp. 14-15).

PLANETARY ORBIT (EXAGGERATED)



Aphelion (orbital point farthest from Sun)

Aphelion of Neptune: 2.8 billion miles



Aphelion of Mars: 154.8 million miles



Year: 87.97 Earth days Mass: 0.06 Earth masses Diameter: 3.051 miles

VENUS Year: 224.7 Earth days Mass: 0.81 Earth masses Diameter: 7,521 miles



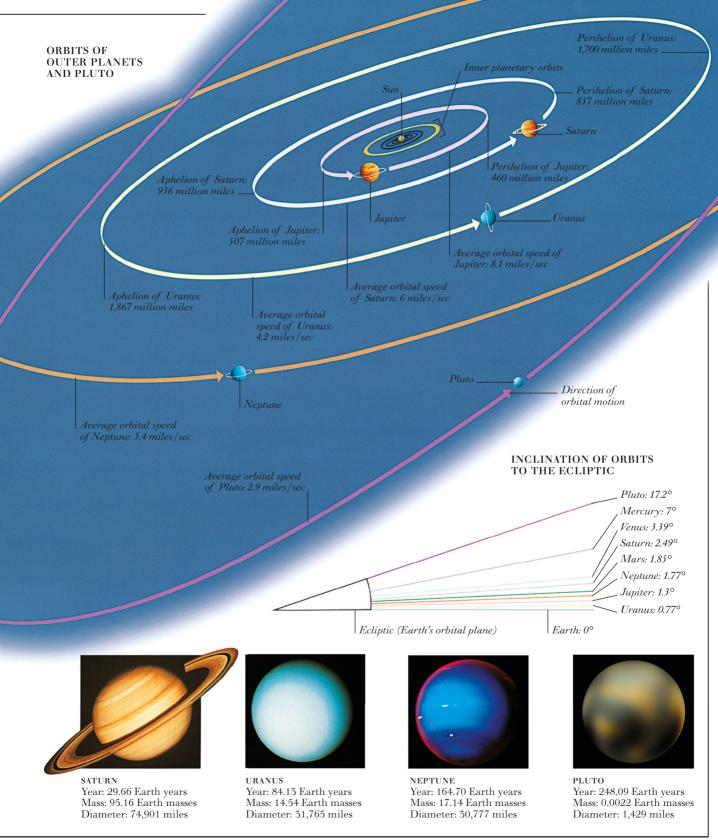
EARTH Year: 365.26 days Mass: 1 Earth mass Diameter: 7,926 miles



MARS Year: 1.88 Earth years Mass: 0.11 Earth masses Diameter: 4,217 miles

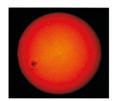


JUPITER Year: 11.87 Earth years Mass: 317.83 Earth masses Diameter: 88,850 miles



The Sun

HOW A SOLAR ECLIPSE OCCURS



SOLAR PHOTOSPHERE

The sun is the star at the center of the solar system. It is about five billion years old and will continue to shine as it does now for about another five billion years. The Sun is a yellow main sequence star (see pp. 22-23) about 870,000 miles (1.4 million km) in diameter. It consists almost entirely of hydrogen and helium. In the Sun's core, hydrogen is converted to helium by nuclear fusion, releasing energy in the process. The energy

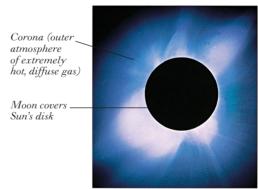
travels from the core, through the radiative and convective zones, to the photosphere (visible surface), where it leaves the Sun in the form of heat and light. On the photosphere there are often dark, relatively cool areas called sunspots, which usually appear in pairs or groups and are caused by the cooling effect of the magnetic field. Other types of solar activity are flares, which are usually associated with sunspots, and prominences. Flares are sudden discharges of high-energy radiation and atomic particles. Prominences are huge loops or filaments of gas extending into the solar atmosphere; some last for hours, others for months. Beyond the photosphere is the chromosphere (inner atmosphere) and the extremely rarified corona (outer atmosphere), which extends millions of miles into space. Tiny particles that escape from the corona give rise to the solar wind, which streams through space at hundreds of miles per second. The chromosphere and corona can be seen from Earth when the Sun is totally eclipsed by the Moon.

Sun Moon passes between Sun and Earth Umbra(inner, total shadow) of Region of MoonEarth from which total eclipse is visible. Penumbra (outer. partial Region of Earth. shadow) from which partial of Moon eclipse is visible Umbra (inner, total Earth shadow) of Earth . Penumbra (outer. partial shadow) of Earth _

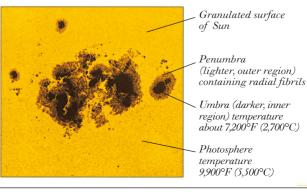
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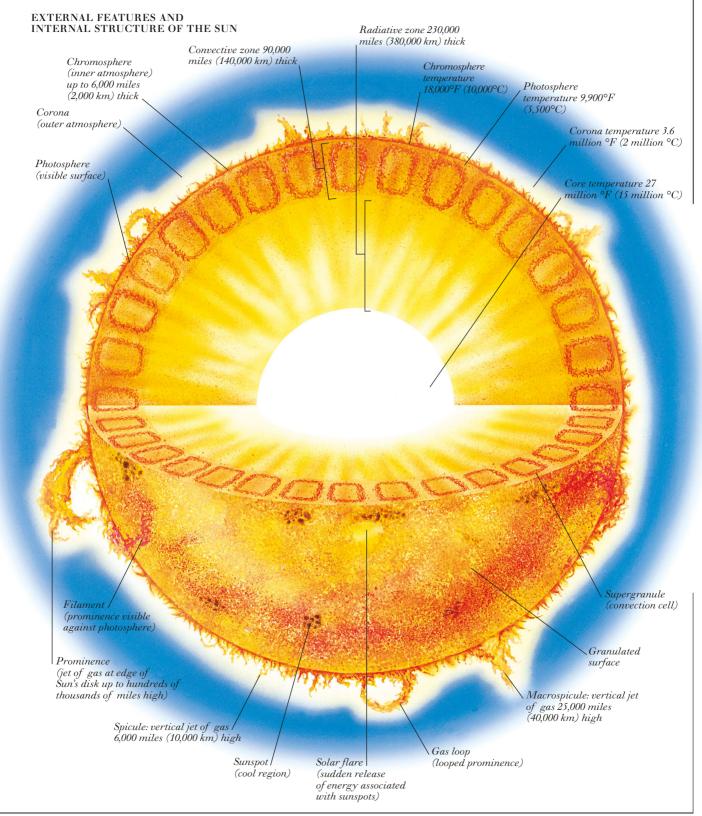


TOTAL SOLAR ECLIPSE



SUNSPOTS





Mercury

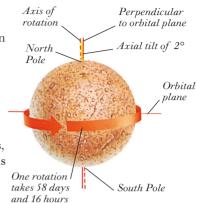


MERCURY

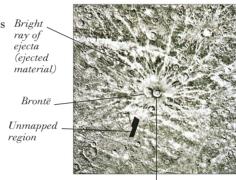
MERCURY IS THE NEAREST PLANET to the Sun, orbiting at an average distance of about 36 million miles (58 million km). Because Mercury is the closest planet to the Sun, it moves faster than any other planet, travelling at an average speed of nearly 30 miles (48 km) per second and completing an orbit in just under 88 days. Mercury is very small (only 40 percent bigger than the Moon) and rocky. Most of the surface has been heavily cratered by the impact of meteorites,

although there are also smooth, sparsely cratered lava-covered plains. The Caloris Basin is the largest crater, measuring about 800 miles (1,300 km) across. It is thought to have been formed when a 38-mile- (60-km-) diameter asteroid hit the planet, and is surrounded by concentric rings of mountains thrown up by the impact. The surface also has many clifflike ridges (called rupes) that are thought to have been formed when the hot core of the young planet cooled and shrank about four billion years Bright ago, buckling the planet's surface in the process. The planet rotates about its axis very slowly, taking nearly 59 Earth days to complete one rotation. As a result, a solar day (sunrise to sunrise) on Mercury is about 176 Earth days—twice as long as the 88-day Mercurian year. Mercury has extreme surface temperatures, ranging from a maximum of 800°F (430°C) on the sunlit side to -270°F (-170°C) on the dark side. At nightfall, the temperature drops very quickly because the planet's atmosphere is almost nonexistent. It consists only of minute amounts of helium and hydrogen captured from the solar wind, plus traces of other gases.

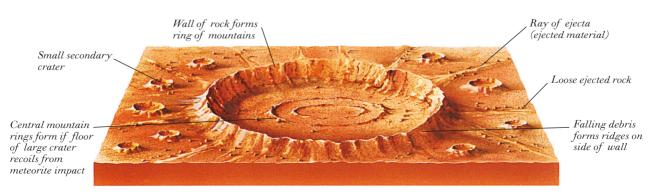
TILT AND ROTATION OF MERCURY



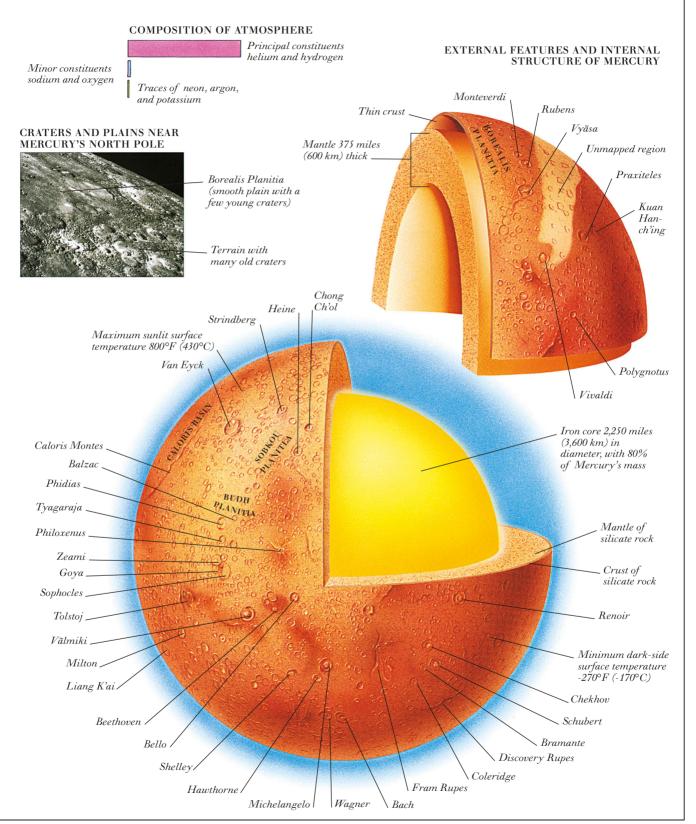
DEGAS AND BRONTË (RAY CRATERS)



Degas with central peak FORMATION OF A RAY CRATER Path of rocky ejecta Path of meteorite (ejected material) Debris thrown colliding with planet Ejecta forms out by impact secondary craters Wall of rock thrown up around crater Impact forms saucer-shaped Loose debris crater on crater floor Fractured rock SECONDARY CRATERING METEORITE IMPACT



RAY CRATER



Venus

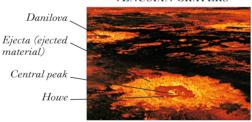


RADAR IMAGE OF VENUS

VENUS IS A ROCKY PLANET and the second planet from the Sun. Venus spins slowly backwards as it orbits the Sun, causing its rotational period to be the longest in the solar system, at about 243 Earth days. It is slightly smaller than Earth and probably has a similar internal structure, consisting of a semisolid metal core, surrounded by a rocky mantle and crust. Venus is the brightest object in the sky after the Sun and Moon because its clouds reflect

sunlight strongly. The main component of the atmosphere is carbon dioxide, which traps heat in a greenhouse effect far stronger than that on Earth. As a result, Venus is the hottest planet, with a maximum surface temperature of about 900°F (480°C). The thick cloud layers contain droplets of sulfuric acid and are driven around the planet by winds at speeds of up to 220 miles (360 km) per hour. Although the planet takes 243 Earth days to rotate once, the high-speed winds cause the clouds to circle the planet in only four Earth days. The high temperature, acidic clouds, and enormous atmospheric pressure (about 90 times greater at the surface than that on Earth) make the environment extremely hostile. However, space probes have managed to land on Venus and photograph its dry, dusty surface. The Venusian surface has also been mapped by probes with radar equipment that can "see" through the cloud layers. Such radar maps reveal a terrain with craters, mountains, volcanoes, and areas where craters have been covered by plains of solidified volcanic lava. There are two large highland regions called Aphrodite Terra and Ishtar Terra.

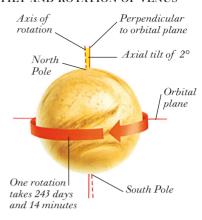
VENUSIAN CRATERS



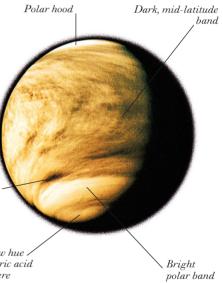
Cloud features swept around planet by winds of up to 220 miles (360 km/h)

> Dirty yellow hue / due to sulfuric acid in atmosphere

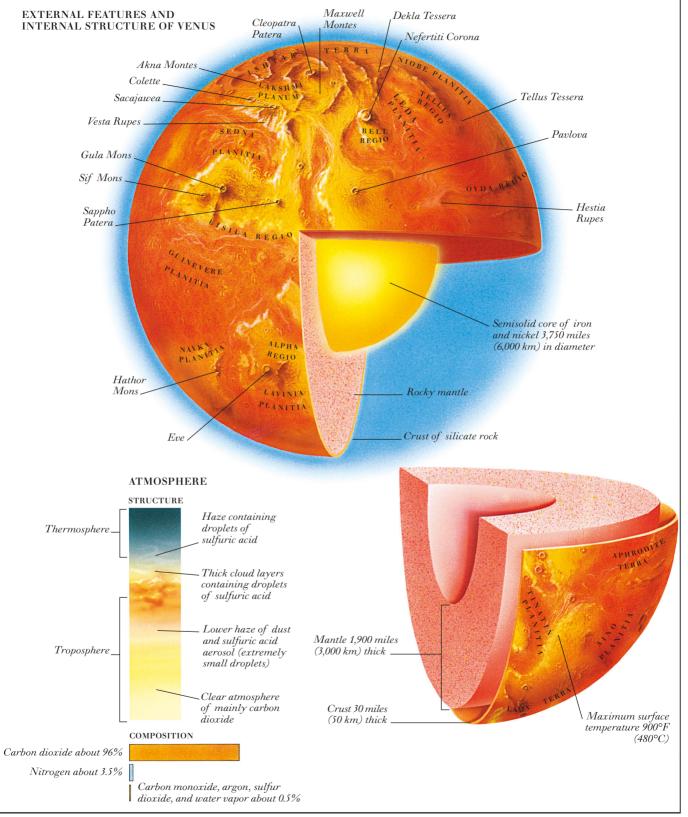
TILT AND ROTATION OF VENUS



CLOUD FEATURES



FALSE-COLOR RADAR MAP Metis Regio Maxwell Montes Bell Regio Tethus Regio OF THE SURFACE OF VENUS Atalanta Planitia Sedna Planitia Leda Planitia Eisila Regio Tellus Regio Guinevere Planitia Niobe Planitia Phoebe Regio Ovda Regio Alpha Regio Thetis Regio Themis Regio Lavinia Planitia Aino Planitia Helen Planitia Lada Terra



The Earth

THE EARTH

THE EARTH IS THE THIRD of the eight planets that orbit the Sun. It is the largest and densest rocky planet, and the only one known to support life. About 70 percent of the Earth's surface is covered by water, which is not found in liquid form on the surface of any other planet. There are four main layers: the inner core, the outer core, the mantle, and the crust. At the heart of the planet the solid inner core has a temperature of about 11,900°F (6,600°C). The heat

from this inner core causes material in the molten outer core and mantle to circulate in convection currents. It is thought that these convection currents generate the Earth's magnetic field, which extends into space as the magnetosphere. The Earth's atmosphere helps screen out some of the harmful radiation from the Sun, stops most meteoroids from reaching the planet's 56 minutes surface, and traps enough heat to prevent extremes of cold. The Earth has one natural satellite, the Moon, which is thought to have formed when a huge asteroid impacted Earth in the distant past.

AGO, THE SOLAR

SYSTEM FORMED

Axis of Axial tilt of 23.4° rotation Orbital North nlane PoleSouth Pole One rotation takes Perpendicular to 23 hours and orbital plane

Microorganisms began

up of oxygen

TILT AND ROTATION OF THE EARTH

to photosynthesize, THE FORMATION OF THE EARTH creating a build The heat of the collisions caused the planet to glow red The cloud formed a disk of material around the young Sun's equator. The disk material stuck together to form planets 4.6 BILLION YEARS THE EARTH WAS 4.5 BILLION YEARS THE CONTINENTS BROKE

FORMED FROM

COLLIDING

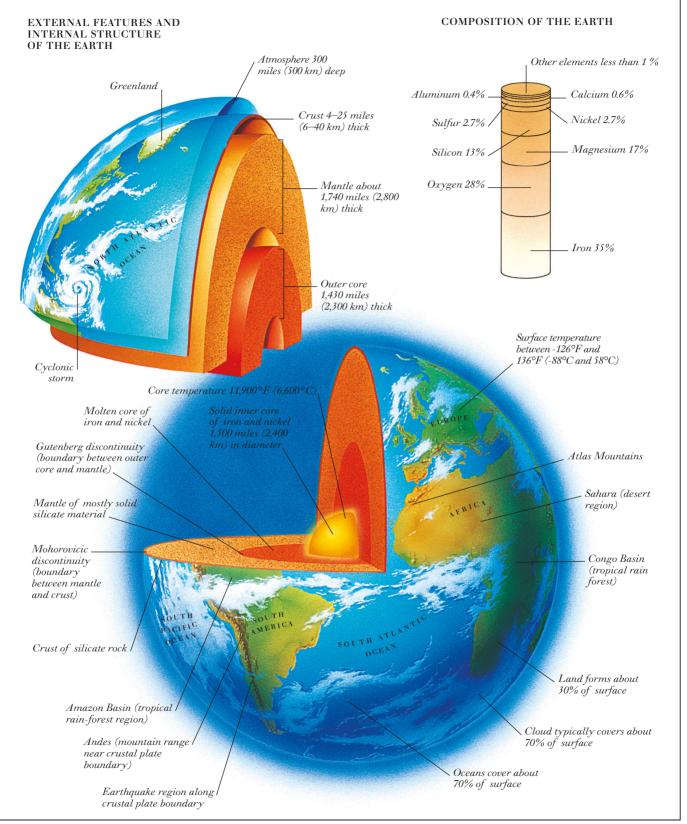
FROM A CLOUD OF ROCKS THE CRUST TO THEIR PRESENT ROCK, ICE, AND GAS POSITIONS Solar wind enters atmosphere and produces aurora Magnetosphere (region affected by magnetic field) Solar wind (stream of electrically charged particles) THE EARTH'S MAGNETOSPHERE Axis of geographic poles Van Allen radiation belt Earth Axis of magnetic poles

AGO THE SURFACE

COOLED TO FORM

UP AND REFORMED.

GRADUALLY MOVING



The Moon

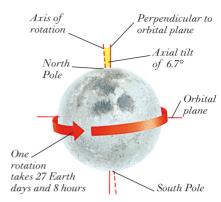


THE MOON FROM EARTH

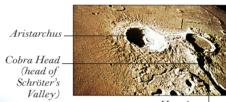
The Moon is the Earth's only natural satellite. It is relatively large for a moon, with a diameter of about 2,155 miles (3,470 km)—just over a quarter that of the Earth. The Moon takes the same time to rotate on its axis as it takes to orbit the Earth (27.3 days), and so the same side (the near side) always faces us. However, the amount of the surface we can see—the phase of the Moon—

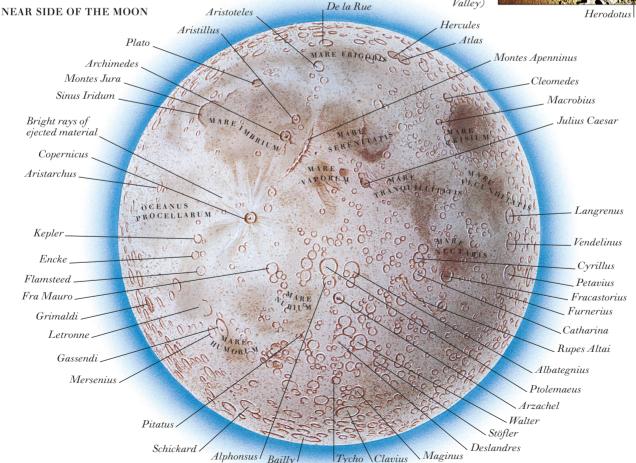
depends on how much of the near side is in sunlight. The Moon is dry and barren, with negligible atmosphere and water. It consists mainly of solid rock, although its core may contain molten rock or iron. The surface is dusty, with highlands covered in craters caused by meteorite impacts, and lowlands in which large craters have been filled by solidified lava to form dark areas called maria or "seas." Maria occur mainly on the near side, which has a thinner crust than the far side. Many of the craters are rimmed by mountain ranges that form the crater walls and can be thousands of feet high.

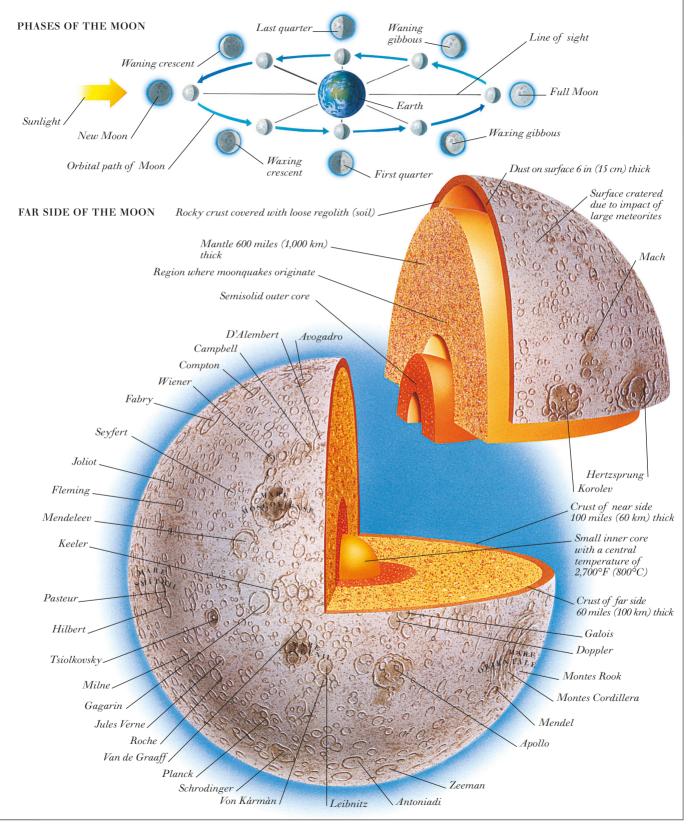
TILT AND ROTATION OF THE MOON



CRATERS ON OCEANUS PROCELLARUM







Mars

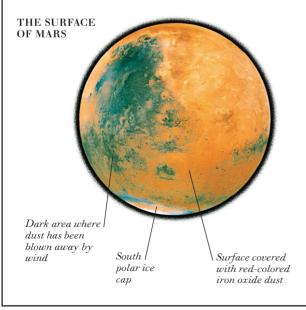


MARS

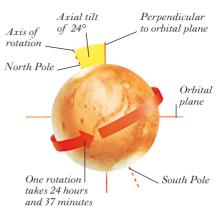
Mars, known as the RED Planet, is the fourth planet from the Sun and the outermost rocky planet. In the 19th century, astronomers first observed what were thought to be signs of life on Mars. These signs included apparent canal-like lines on the surface, and dark patches that were thought to be vegetation. It is now known that the "canals" are an optical illusion, and the dark patches are areas where the red dust that

covers most of the planet has been blown away. The fine dust particles are often whipped up by winds into dust storms that occasionally obscure almost all the surface. Residual fine dust in the atmosphere gives the

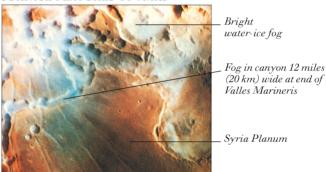
Martian sky a pinkish hue. The northern hemisphere of Mars has many large plains formed of solidified volcanic lava, whereas the southern hemisphere has many craters and large impact basins. There are also several huge, extinct volcanoes, including Olympus Mons, which, at 370 miles (600 km) across and 15 miles (25 km) high, is the largest known volcano in the solar system. The surface also has many canyons and branching channels. The canyons were formed by movements of the surface crust, but the channels are thought to have been formed by flowing water that has now dried up. The Martian atmosphere is much thinner than Earth's, with only a few clouds and morning mists. Mars has two tiny, irregularly shaped moons called Phobos and Deimos. Their small size indicates that they may be asteroids that have been captured by the gravity of Mars.



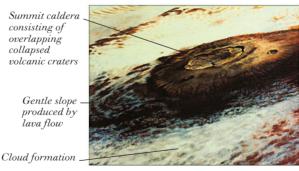
TILT AND ROTATION OF MARS



SURFACE FEATURES OF MARS



NOCTIS LABYRINTHUS (CANYON SYSTEM)



OLYMPUS MONS (EXTINCT SHIELD VOLCANO)

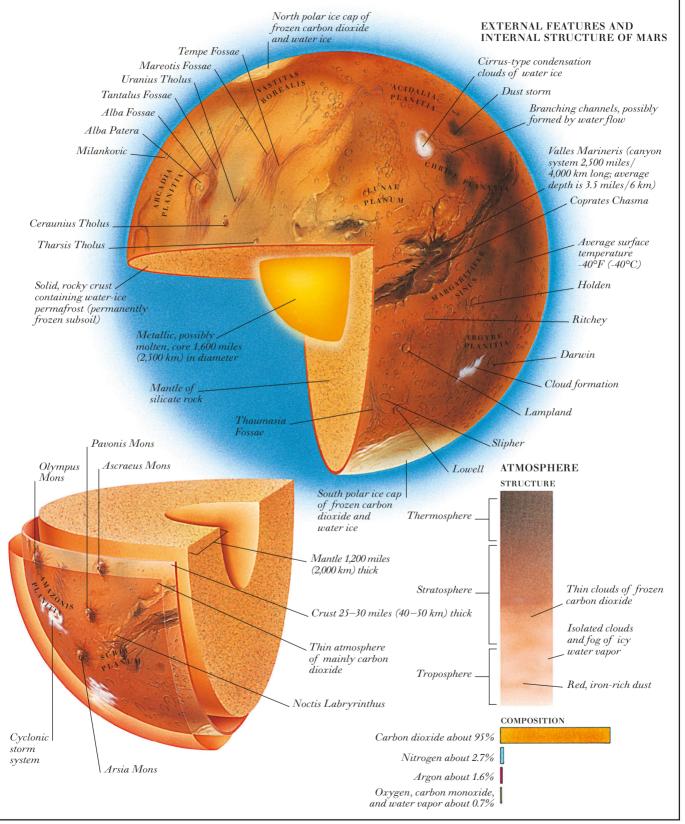
MOONS OF MARS



PHOBOS Average diameter: 14 miles Average distance from planet: 5,800 miles



DEIMOS Average diameter: 8 miles Average distance from planet: 14,600 miles



Jupiter

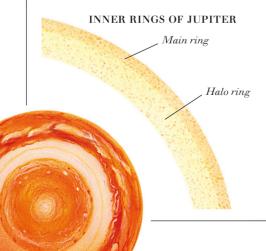


JUPITER

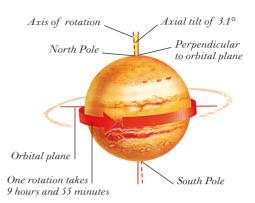
JUPITER IS THE FIFTH PLANET from the Sun and the innermost of the four giant planets. It is the largest and the most massive planet, with a diameter about 11 times that of the Earth and a mass about 2.5 times the combined mass of the seven other planets. Jupiter is thought to have a small rocky core surrounded by an inner mantle of metallic hydrogen (liquid hydrogen that acts

like a metal). Outside the inner mantle is an outer mantle of liquid hydrogen and helium that merges into the gaseous atmosphere. Jupiter's rapid rate of rotation causes the clouds in its atmosphere to form belts and zones that encircle the planet parallel to the equator. Belts are dark, low-lying, relatively warm cloud layers, and zones are bright, high-altitude, cooler cloud layers. Within the belts and zones, turbulence causes the

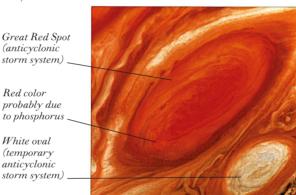
formation of cloud features such as white ovals and red spots, both of which are huge storm systems. The most prominent cloud feature is a storm called the Great Red Spot, which consists of a spiraling column of clouds three times wider than the Earth that rises about five miles (8 km) above the upper cloud layer. Jupiter has a thin, faint, main ring, inside which is a tenuous halo ring of tiny particles. Beyond the main ring's outer edge is a broad and faint two-part gossamer ring. There are 63 known Jovian moons. The four largest moons (called the Galileans) are Ganymede, Callisto, Io, and Europa. Ganymede and Callisto are cratered and icy. Europa is smooth and icy and is thought to have a subsurface water ocean. Io is covered in bright red, orange, and yellow splotches. This coloring is caused by sulfurous material from active volcanoes that shoot plumes of lava hundreds of miles above the surface.



TILT AND ROTATION OF JUPITER



GREAT RED SPOT AND WHITE OVAL



GALILEAN MOONS OF JUPITER



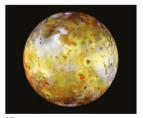
EUROPA Diameter: 1,950 miles Average distance from planet: 416,900 miles



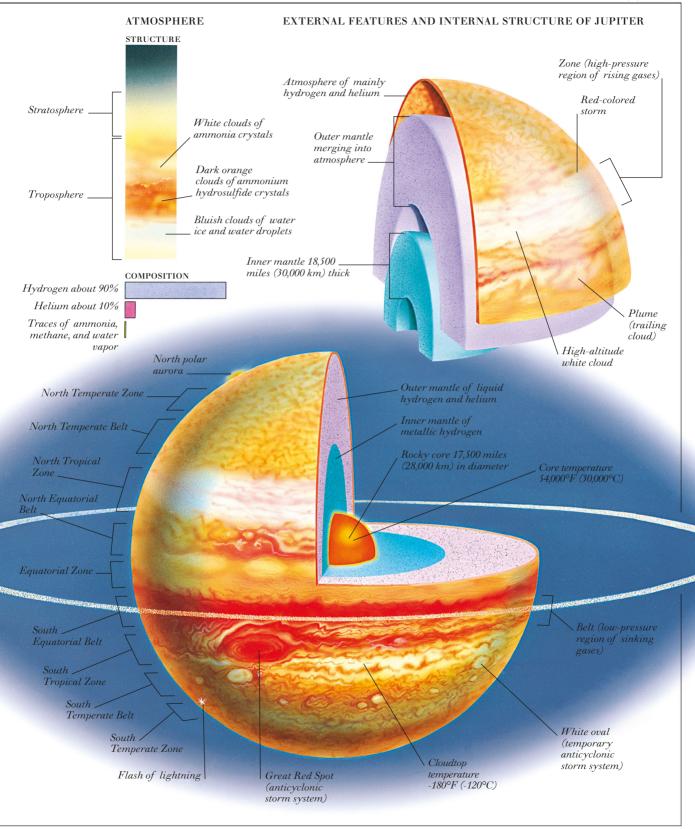
GANYMEDE Diameter: 3,270 miles Average distance from planet: 664,900 miles



CALLISTO Diameter: 2,983 miles Average distance from planet: 1,168,200 miles



Diameter: 2,263 miles Average distance from planet: 262,100 miles



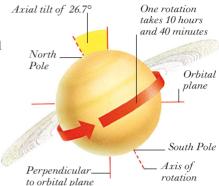
Saturn

FALSE-COLOR IMAGE OF SATURN

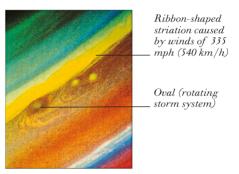
SATURN IS THE SIXTH PLANET from the Sun. It is a gas giant almost as big as Jupiter, with an equatorial diameter of about 75,000 miles (120,500 km). Saturn is thought to consist of a small core of rock and ice surrounded by an inner mantle of metallic hydrogen (liquid hydrogen that acts like a metal). Outside the inner mantle is an outer mantle of liquid hydrogen that merges into a gaseous atmosphere. Saturn's clouds form belts and zones similar to those on

Jupiter, but obscured by overlying haze. Storms and eddies, seen as red or white ovals, occur in the clouds. Saturn has an extremely thin but wide system of rings that is about half a mile (1 km) thick but extends outward to about 260,000 miles (420,000 km) from the planet's surface. The main rings comprise thousands of narrow ringlets, each made of icy rock lumps that range in size from tiny particles to chunks several yards across. The D, E, and G rings are very faint, the F ring is brighter, and the A, B, and C rings are bright enough to be seen from Earth with binoculars. In 2009, a huge dust ring was discovered 4 million miles (6 million km) beyond the main system. Saturn has more than 60 known moons, some of which orbit inside the rings and are thought to exert a gravitational influence on the shapes of the rings. Unusually, seven of the moons are co-orbital—they share an orbit with another moon. Astronomers believe that such co-orbital moons may have originated from a single satellite that broke up.

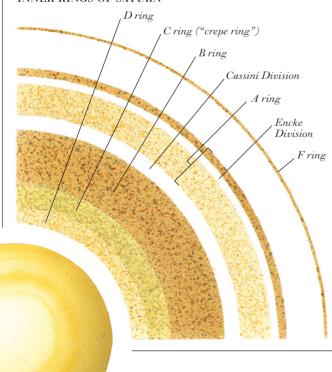
TILT AND ROTATION OF SATURN



FALSE-COLOR IMAGE OF SATURN'S CLOUD FEATURES



INNER RINGS OF SATURN



MOONS OF SATURN



ENCELADUS Diameter: 509 miles Average distance from planet: 148,000 miles



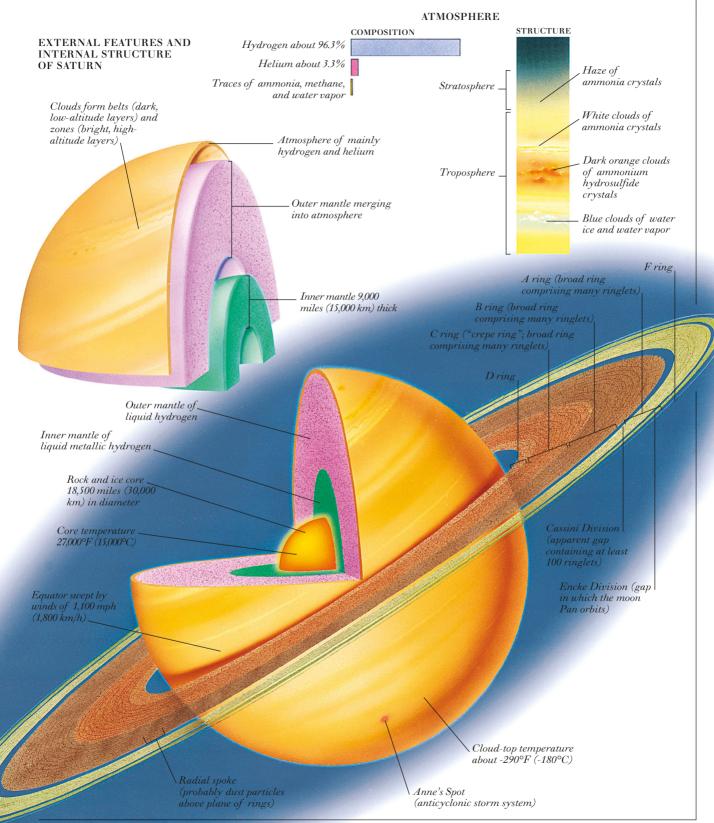
DIONE
Diameter: 695 miles
Average distance from
planet: 254,000 miles



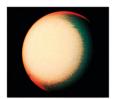
TETHYS Diameter: 652 miles Average distance from planet: 183,000 miles



MIMAS Diameter: 247 miles Average distance from planet: 115,600 miles



Uranus



FALSE-COLOR IMAGE OF URANUS

URANUS IS THE SEVENTH PLANET from the Sun and the third largest, with a diameter of about 32,000 miles (51,000 km). It is thought to consist of a dense mixture of different types of ice and gas around a solid core. Its atmosphere contains traces of methane, giving the planet a blue-green hue, and the temperature at the cloud tops is about -350°F (-210°C). Uranus is the most featureless planet to have been closely observed:

only a few icy clouds of methane have been seen so far. Uranus is unique among the planets in that its axis of rotation lies close to its orbital plane. As a result of its strongly tilted rotational axis, Uranus rolls on its side along its orbital path around the Sun, whereas other planets spin more or less upright. Uranus is encircled by main rings that consist of rocks interspersed with dust lanes and two distant outer rings made of dust. The rings contain some of the darkest matter in the solar system and are extremely narrow, making them difficult to detect: most of them are less than 6 miles (10 km) wide, whereas most of Saturn's rings are thousands of miles in width. There are 27 known Uranian moons, all of which are icy and most of which are farther out than the rings. The 13 inner moons are small and dark, with diameters of less than 100 miles (160 km), and the five major moons are between about 290 and 1,000 miles (470 and 1,600 km) in diameter. The major moons have a wide variety of surface features. Miranda has the most varied surface, with cratered areas broken up by huge ridges and cliffs 12 miles (20 km) high. Beyond these are nine much more distant moons with diameters less than 90 miles (150 km).

RINGS OF URANUS Epsilon ring Delta ring RINGS AND DUST LANES Gamma ring Eta ring Beta ring Alpha ring Rings 4 and 5 Ring 6 Zeta ring

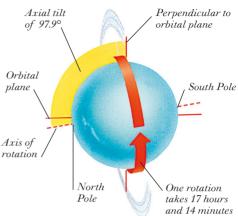


ARIEL Diameter: 720 miles Average distance from planet: 118,800 miles



UMBRIEL Diameter: 726 miles Average distance from planet: 165,500 miles

TILT AND ROTATION OF URANUS



MAJOR MOONS



MIRANDA Diameter: 295 miles Average distance from planet: 80,700 miles



TITANIA Diameter: 981 miles Average distance from planet: 270,900 miles



OBERON Diameter: 946 miles Average distance from planet: 362,000 miles

Icy clouds of / frozen methane

blown by winds of 185 mph (300 km/h) rocks interspersed

with dust lanes

Neptune and Pluto



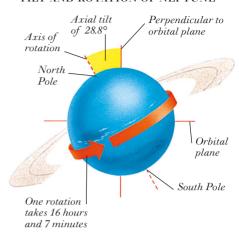
FALSE-COLOR IMAGE OF NEPTUNE

NEPTUNE IS the farthest planet from the Sun, at an average distance of about 2.8 billion miles (4.5 billion km). Neptune is the smallest of the giant planets and is thought to consist of a small rocky core surrounded by a mixture of liquids and gases. Several transient cloud features have been observed in its atmosphere. The largest of these were the Great Dark Spot, which was as wide as the Earth, the Small Dark Spot, and the Scooter.

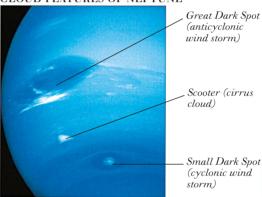
The Great and Small Dark Spots were huge storms that were swept around the planet by winds of about 1,200 miles (2,000 km) per hour. The Scooter was a large area of cirrus cloud. Neptune has six tenuous rings and 13 known moons. Triton is the largest Neptunian moon and the coldest object in the solar system, with a temperature of -390°F (-240°C). Unlike most moons in the solar system, Triton orbits its mother planet in the opposite direction of the planet's rotation. The region extending out from Neptune's orbit is populated by Kuiper Belt objects and dwarf planets. They make a doughnutshaped belt called the Kuiper Belt. The Kuiper Belt objects are a mix of rock and ice, irregular in shape, and less than 600 miles (1,000 km) across. The larger dwarf planets, which include Pluto, are almost round bodies. Pluto was the first object discovered beyond Neptune and was considered a planet until the dwarf planet category was introduced in 2006. It is made of rock and ice and is 1,365 miles (2,274 km) across. It has three known moons. The largest, Charon, is about half Pluto's size and the two probably had a common origin.

Adams ring and unnamed ring on its inner edge Arago ring Lassell ring Galle ring

TILT AND ROTATION OF NEPTUNE



CLOUD FEATURES OF NEPTUNE



HIGH-ALTITUDE CLOUDS

Methane cirrus clouds
25 miles (40 km) above
main cloud deck

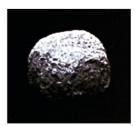
Cloud shadow

Main cloud deck
blown by winds at speeds
of about 12,000 miles
(2,000 km/h)

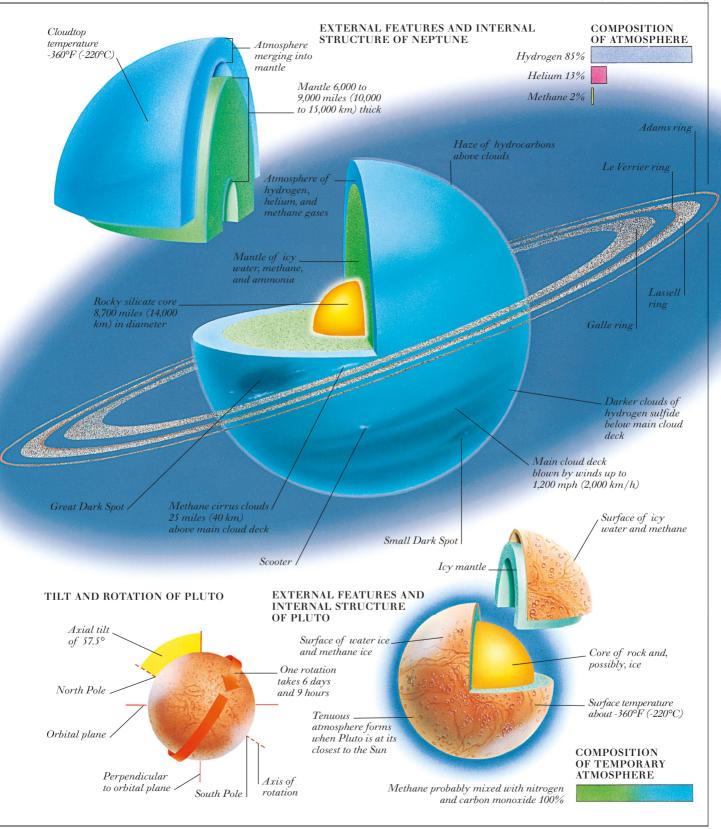
MOONS OF NEPTUNE



TRITON
Diameter: 1,681 miles
Average distance from
planet: 220,500 miles



PROTEUS Diameter: 259 miles Average distance from planet: 73,100 miles



Asteroids, comets, and meteoroids



ASTEROID 951 GASPRA

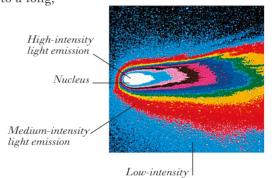
ASTEROIDS, COMETS, AND METEOROIDS are all debris remaining from the nebula from which the solar system formed 4.6 billion years ago. Asteroids are rocky bodies up to about 600 miles (1,000 km) in diameter, although most are much smaller. Most of them orbit the Sun in the asteroid belt, which lies between the orbits of Mars and Jupiter. Cometary nuclei exist in a huge cloud (called the Oort Cloud) that surrounds the planetary part of the solar system. They are made of frozen water and dust and are a few miles in

diameter. Occasionally, a comet is deflected from the Oort Cloud on to a long, elliptical path that brings it much closer to the Sun. As the comet approaches the Sun, the cometary nucleus starts to vaporize in the heat, producing both a brightly shining coma (a huge sphere of gas and dust around the nucleus), and a gas tail, and a dust tail. Meteoroids are small chunks of stone or stone and iron, which are fragments of asteroids or comets. Meteoroids range in size from tiny dust particles to objects tens of meters across. If a meteoroid enters the Earth's atmosphere, it is heated by friction and appears as a glowing streak of light called a meteor (also known as a shooting star). Meteor showers occur when the Earth passes through the trail of dust particles left by a comet. Most meteoroids burn up in the atmosphere. The remnants of the few that are large enough to reach the Earth's surface are termed meteorites.

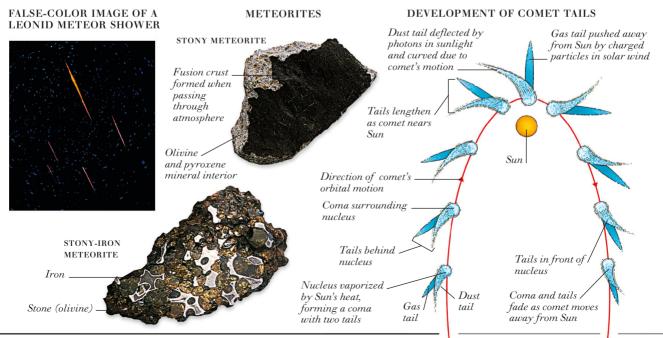
OPTICAL IMAGE OF HALLEY'S COMET

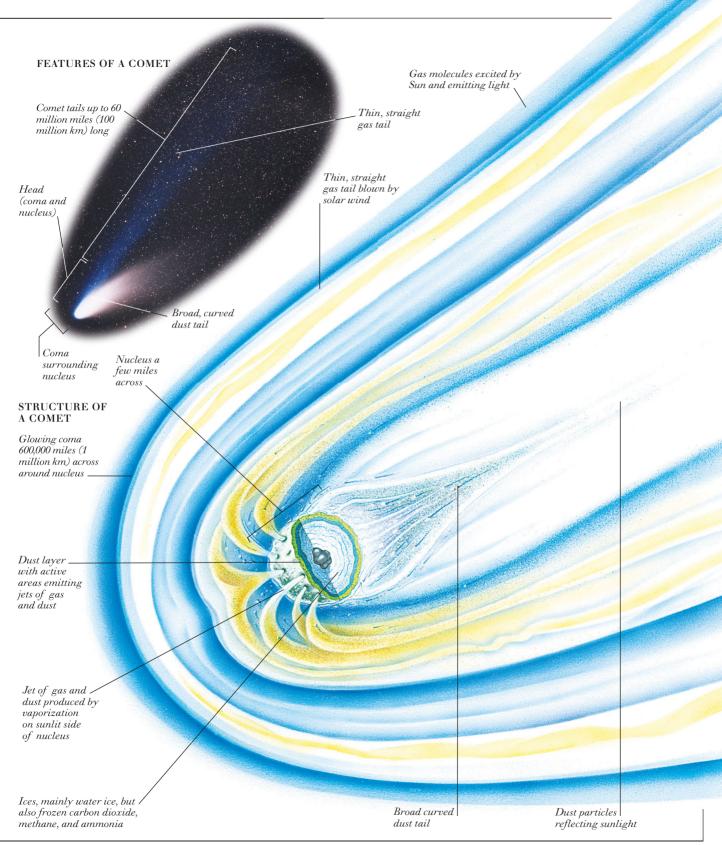


FALSE-COLOR IMAGE OF HALLEY'S COMET



light emission





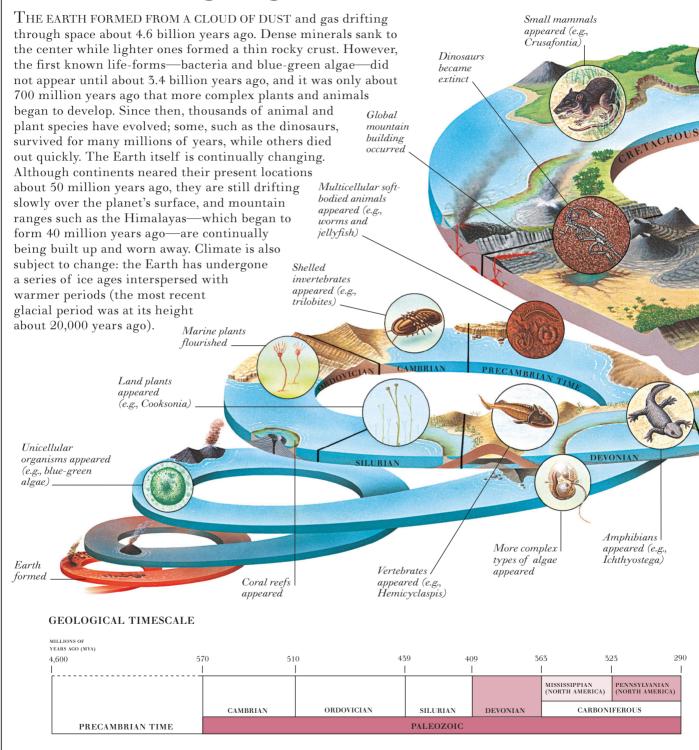


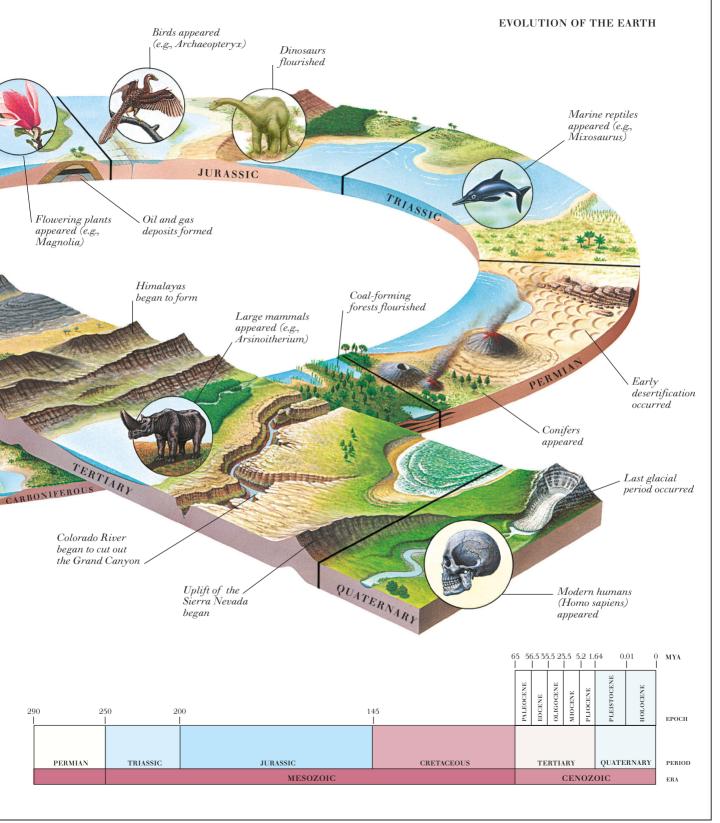


Prehistoric Earth

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${ m A}$ MPHIBIANS AND ${ m R}$ EPTILES \sim 8	30
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The changing Earth



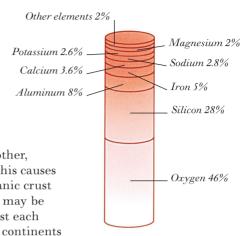


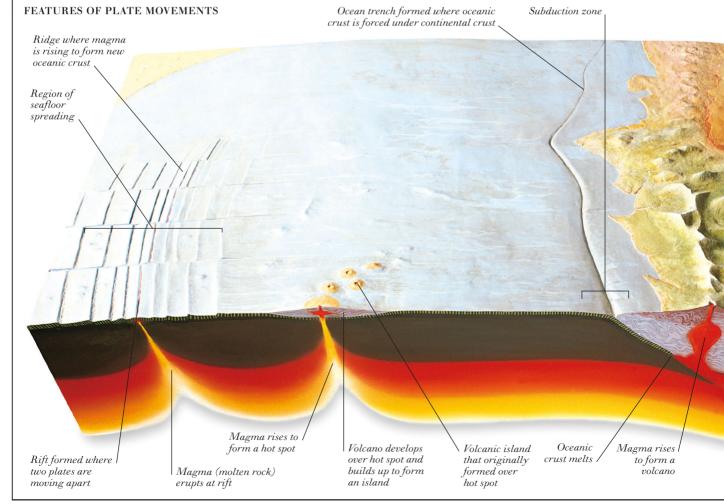
The Earth's crust

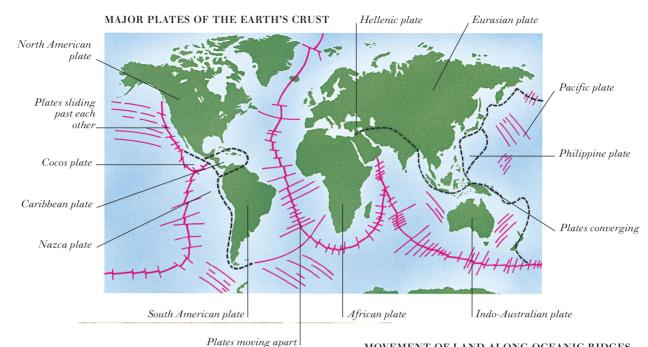
The Earth's Crust is the solid outer shell of the Earth. It includes continental crust (about 25 miles/40 km thick) and oceanic crust (about four miles/6 km thick). The crust and the topmost layer of the mantle form the lithosphere. The lithosphere consists of semirigid plates that move relative to each other on the underlying asthenosphere (a partly molten layer of the mantle). This process is known as plate tectonics and helps explain continental drift. Where two plates move apart, there are rifts in the crust. In mid-ocean, this movement results in seafloor spreading and the formation of ocean ridges; on continents, crustal spreading can form rift valleys. When plates move toward each other, one may be subducted beneath (forced under) the other. In mid-ocean, this causes ocean trenches, seismic activity, and arcs of volcanic islands. Where oceanic crust is subducted beneath continental crust or where continents collide, land may be uplifted and mountains formed (see pp. 62–65). Plates may also slide past each other—along the San Andreas fault, for example. Crustal movement on continents

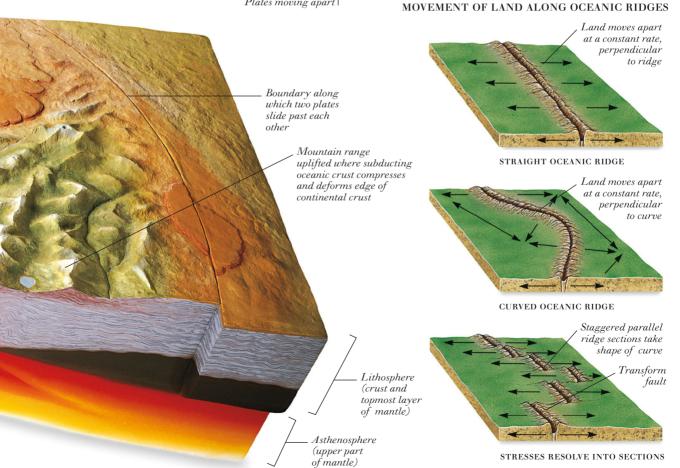
may result in earthquakes, while movement under the seabed can lead to tidal waves.

ELEMENTS IN THE EARTH'S CRUST









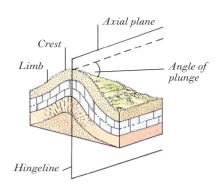
Faults and folds

THE CONTINUOUS MOVEMENT of the Earth's crustal plates (see pp. 58–59) can squeeze, stretch, or break rock strata, deforming them and producing faults and folds. A fault is a fracture in a rock along which there is movement of one side relative to the other. The movement can be vertical, horizontal, or oblique (vertical and horizontal). Faults develop when rocks are subjected to compression or tension. They tend to occur in hard, rigid rocks, which are more likely to break than bend. The smallest faults occur in single mineral crystals and are microscopically small, whereas the largest—the Great Rift Valley in Africa, which formed between 5 million and 100,000 years ago—is more than 6,000 miles (9,000 km) long. A fold is a bend in a rock layer caused by compression. Folds occur in elastic rocks, which tend to bend rather than break. The two main types of fold are anticlines (upfolds) and synclines (downfolds). Folds vary in size from a few millimeters long to folded mountain ranges hundreds of miles long, such as the Himalayas (see pp. 62-63) and the Alps, which are repeatedly folding. In addition to faults and folds, other features associated with rock deformations include boudins, mullions, and en échelon fractures.

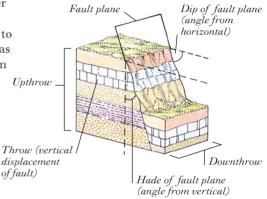
FOLDED ROCK Crest of anticline Plunge limbs

SECTION THROUGH FOLDED ROCK STRATA THAT HAVE BEEN ERODED Dipping bed Anticlinal fold

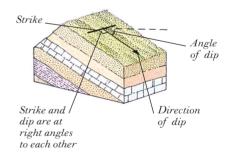
STRUCTURE OF A FOLD



STRUCTURE OF A FAULT



STRUCTURE OF A SLOPE

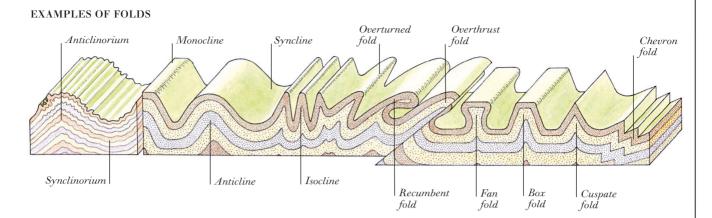


Monoclinal fold

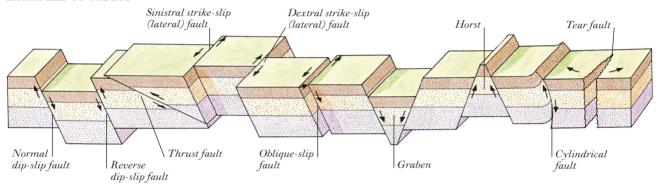
Mineral-filled fault

Upper Carboniferous Millstone Grit

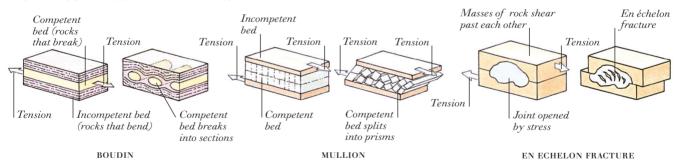
Lower Carboniferous Limestone



EXAMPLES OF FAULTS



SMALL-SCALE ROCK DEFORMATIONS





Upper Carboniferous Millstone Grit

Upper Carboniferous Coal Measures

Mountain building

The processes involved in mountain building—termed orogenesis—occur as a result of the movement of the Earth's crustal plates (see pp. 58–59). There are three main types of mountains: volcanic mountains, fold mountains, and block mountains. Most volcanic mountains have been formed along plate boundaries where plates have come together or Himalayas moved apart and lava and other debris have been ejected onto the

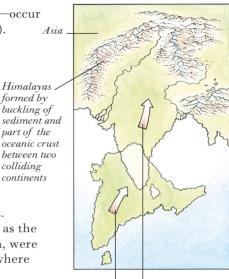
Earth's surface. The lava and debris may have built up to form a dome around the vent of a volcano. Fold mountains are formed

BHAGIRATHI PARBAT. HIMALAYAS

part of the where plates push together and oceanic crust cause the rock to buckle upward. between two Where oceanic crust meets less dense colliding continents continental crust, the oceanic crust is forced under the continental crust. The continental crust is buckled by the impact. This is how folded mountain ranges, such as the Appalachian Mountains in North America, were formed. Fold mountains are also formed where two areas of continental crust meet. The Himalayas, for example, began to form when India collided with Asia, buckling the sediments

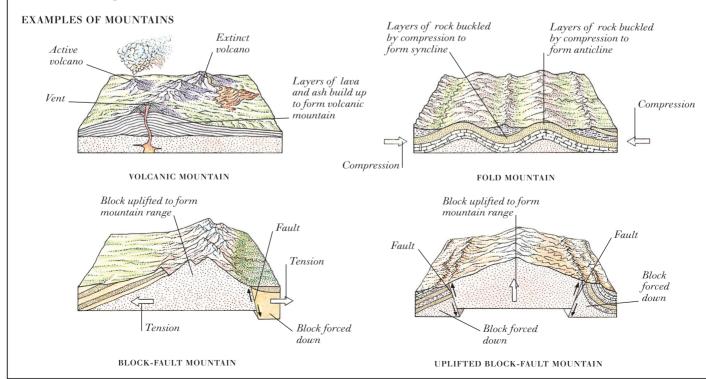
FORMATION OF THE HIMALAYAS

formed by

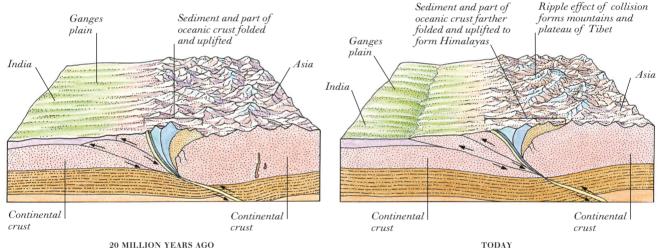


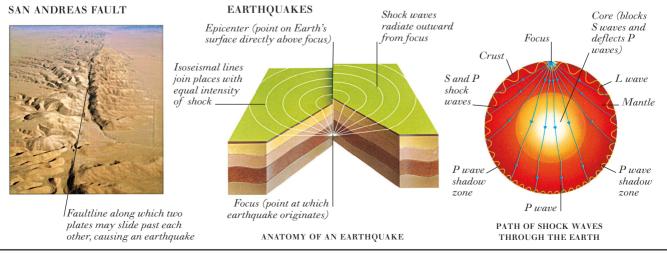
India collides India moves with Asia about 40 north million years ago

and parts of the oceanic crust between them. Block mountains are formed when a block of land is uplifted between two faults as a result of compression or tension in the Earth's crust (see pp. 60-61). Often, the movement along faults has taken place gradually over millions of years. However, two plates may cause an earthquake by suddenly sliding past each other along a faultline.



STAGES IN THE FORMATION OF THE HIMALAYAS Sediment and part of Ocean area oceanic crust folded by becomes smaller continental collision Sediment Sediment as plates converge Asia India India Asia moves Volcano toward Continental Asiacrust Magma rises to Continental Oceanic crust forced Continental Oceanic crust forced farther Continental form volcanoes crust under continental crust crust under continental crust crust 60 MILLION YEARS AGO 40 MILLION YEARS AGO Ripple effect of collision Sediment and part of Sediment and part of oceanic crust farther forms mountains and Ganges plateau of Tibet folded and uplifted to plain oceanic crust folded and uplifted form Himalayas Ganges plain India AsiaAsia

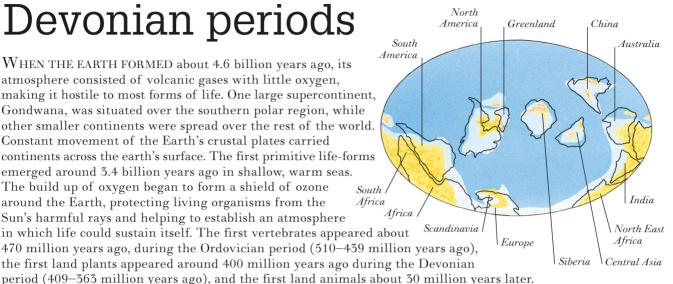




Precambrian to Devonian periods

WHEN THE EARTH FORMED about 4.6 billion years ago, its atmosphere consisted of volcanic gases with little oxygen, making it hostile to most forms of life. One large supercontinent, Gondwana, was situated over the southern polar region, while other smaller continents were spread over the rest of the world. Constant movement of the Earth's crustal plates carried continents across the earth's surface. The first primitive life-forms emerged around 3.4 billion years ago in shallow, warm seas. The build up of oxygen began to form a shield of ozone Africa around the Earth, protecting living organisms from the Sun's harmful rays and helping to establish an atmosphere in which life could sustain itself. The first vertebrates appeared about

MIDDLE ORDOVICIAN POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF PRECAMBRIAN TO DEVONIAN PLANT GROUPS



A PRESENT-DAY CLUBMOSS (Lycopodium sp.)



A PRESENT-DAY LAND PLANT (Asparagus setaceous)



FOSSIL OF AN EXTINCT LAND PLANT (Cooksonia hemisphaerica)



FOSSIL OF AN EXTINCT SWAMP PLANT (Zosterophyllum llanoveranum)

EXAMPLES OF PRECAMBRIAN TO DEVONIAN TRILOBITES



ACADAGNOSTUS Group: Agnostidae Length: 1/3 in (8 mm)



PHACOPS Group: Phacopidae Length: 13/4 in (4.5 cm)



OLENELLUS Group: Olenellidae Length: $2\frac{1}{2}$ in (6 cm)



ELRATHIA Group: Ptychopariidae Length: ¾ in (2 cm)

THE EARTH DURING THE MIDDLE ORDOVICIAN PERIOD

Siberia Laurentia China Kazakstania Gondwana Baltica

TRACE FOSSIL (Mawsonites spriggi)

EXAMPLES OF EARLY MARINE INVERTEBRATES



FOSSIL NAUTILOID (Estonioceras perforatum)



FOSSIL BRACHIOPOD (Dicoelosia bilobata)



FOSSIL GRAPTOLITE (Monograptus convolutus)

EXAMPLES OF DEVONIAN FISH



RHAMPHODOPSIS Group: Ptyctodontidae Length: 6 in (15 cm)



CHEIRACANTHUS Group: Acanthodidae Length: 12 in (30 cm)



PTERASPIS Group: Pteraspidae Length: 10 in (25 cm)



PTERICHTHYODES Group: Asterolepididae Length: 6 in (15 cm)



COCCOSTEUS Group: Coccosteidae Length: 14 in (35 cm)



CHEIROLEPIS Group: Cheirolepidae Length: 6¾ in (17 cm)



BOTHRIOLEPIS Group: Bothriolepididae Length: 16 in (40 cm)

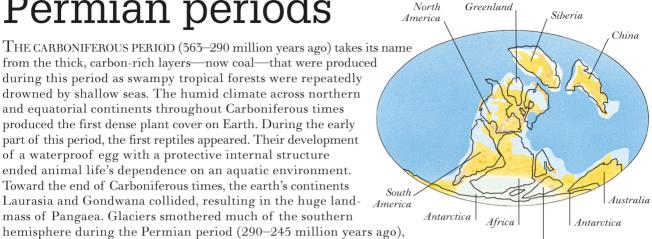


CEPHALASPIS Group: Cephalaspidae Length: 8⁵/₄ in (22 cm)

Carboniferous to Permian periods

THE CARBONIFEROUS PERIOD (363–290 million years ago) takes its name from the thick, carbon-rich layers—now coal—that were produced during this period as swampy tropical forests were repeatedly drowned by shallow seas. The humid climate across northern and equatorial continents throughout Carboniferous times produced the first dense plant cover on Earth. During the early part of this period, the first reptiles appeared. Their development of a waterproof egg with a protective internal structure ended animal life's dependence on an aquatic environment. Toward the end of Carboniferous times, the earth's continents Laurasia and Gondwana collided, resulting in the huge landmass of Pangaea. Glaciers smothered much of the southern

LATE CARBONIFEROUS POSITIONS OF PRESENT-DAY LANDMASSES



covering Antarctica, parts of Australia, and much of South America, Africa, and India. Ice locked up much of the world's water and large areas of the northern hemisphere experienced a drop in sea level. Away from the poles, deserts and a hot dry climate predominated. As a result of these conditions, the Permian period ended with the greatest mass extinction of life on Earth ever.

EXAMPLES OF CARBONIFEROUS AND PERMIAN PLANT GROUPS



A PRESENT-DAY FIR (Abies concolor)



FOSSIL OF AN EXTINCT FERN (Zeilleria frenzlii)



FOSSIL OF AN EXTINCT HORSETAIL (Equisetites sp.)



FOSSIL OF AN EXTINCT CLUBMOSS (Lepidodendron sp.)

EXAMPLES OF CARBONIFEROUS AND PERMIAN TREES



PECOPTERIS Group: Marattiaceae Height: 13 ft (4 m)



PARIPTERIS Group: Medullosaceae Height: 16 ft 6 in (5 m)



MARIOPTERIS Group: Lyginopteridales Height: 16 ft 6 in (5 m)



MEDULLOSA Group: Medullosaceae Height: 16 ft 6 in (5 m)

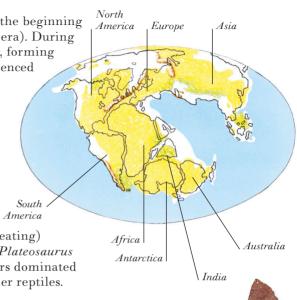
EXAMPLES OF CARBONIFEROUS THE EARTH DURING THE LATE CARBONIFEROUS PERIOD AND PERMIAN ANIMALS Siberia Laurussia China SKULL OF AN EXTINCT SYNAPSID (Dimetrodon loomisi) UralMountains Caledonian Mountains FOSSIL TEETH OF AN EXTINCT SHARK $(Helicoprion\ bessonowi)$ Appalachian . Mountains Gondwana MODEL OF AN EXTINCT EARLY REPTILELIKE ANIMAL (Westlothiana lizziae) LEPIDODENDRON CORDAITES GLOSSOPTERIS ALETHOPTERIS Group: Glossopteridaceae Height: 26 ft (8 m) Group: Medullosaceae Group: Lepidodendraceae Group: Cordaitacea Height: 100 ft (30 m) Height: 33 ft (10 m) Height: 16 ft 6 in (5 m)

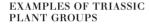
Triassic period

TRIASSIC POSITIONS OF PRESENT-DAY LANDMASSES

THE TRIASSIC PERIOD (250–200 million years ago) marked the beginning of what is known as the Age of the Dinosaurs (the Mesozoic era). During this period, the present-day continents were massed together, forming one huge continent known as Pangaea. This landmass experienced extremes of climate, with lush green areas around the coast or by lakes and rivers, and arid deserts in the interior. The only forms of plant life were nonflowering plants, such as conifers, ferns, cycads, and ginkgos; flowering plants had not yet evolved. The principal forms of animal life included diverse, often gigantic, amphibians, rhynchosaurs ("beaked lizards"), and primitive crocodilians. Dinosaurs first appeared about 230 million years ago, at the beginning of the Late Triassic period. Among the earliest dinosaurs were the carnivorous (flesh-eating) herrerasaurids, such as Herrerasaurus and Staurikosaurus Early herbiyorous (plant-eating)

Herrerasaurus and Staurikosaurus. Early herbivorous (plant-eating) dinosaurs first appeared in Late Triassic times and included Plateosaurus and Technosaurus. By the end of the Triassic period, dinosaurs dominated Pangaea, possibly contributing to the extinction of many other reptiles.







CYCAD (Cycas revoluta)



A PRESENT-DAY GINKGO (Ginkgo biloba)



A PRESENT-DAY CONIFER (Araucaria araucana)



FOSSIL OF AN EXTINCT FERN (Pachypteris sp.)



FOSSIL LEAF OF AN EXTINCT CYCAD (Cycas sp.)

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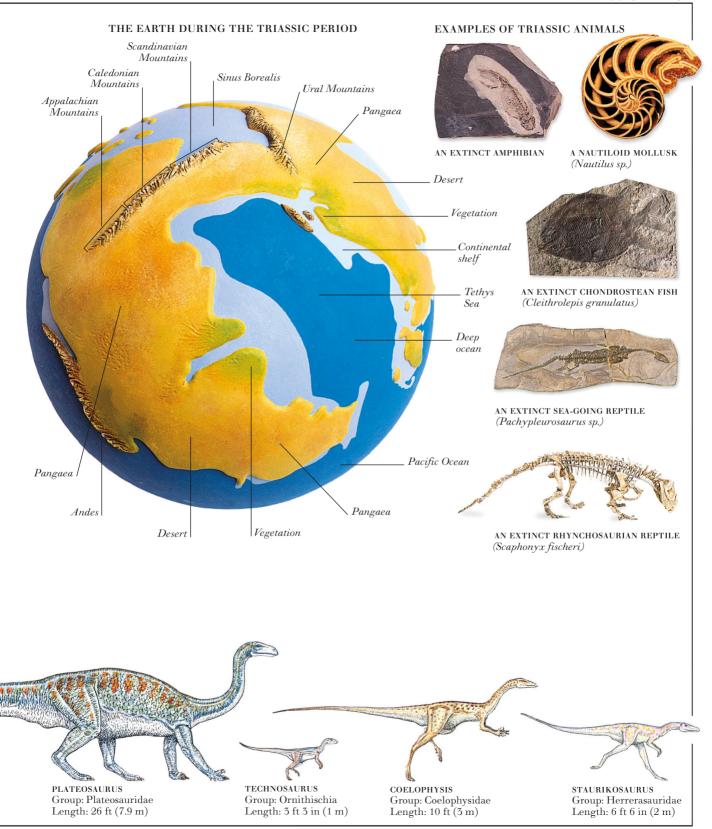
EXAMPLES OF TRIASSIC DINOSAURS



MUSSAURUS Group: Sauropodomorpha Length: 6 ft 6 in-10 ft (2-3 m)



PISANOSAURUS Group: Ornithischia Length: 3 ft (90 cm)



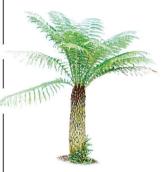
Jurassic period

THE JURASSIC PERIOD, the middle part of the Mesozoic era, lasted from 199 to 145 million years ago. During Jurassic times, the landmass of Pangaea broke up into the continents of Gondwana and Laurasia, and sea levels rose, flooding areas of lower land. The Jurassic climate was warm and moist. Plants such as ginkgos, horsetails, and conifers thrived, and giant redwood trees appeared, as did the first flowering plants. The abundance of plant food coincided with the proliferation of herbivorous (plant-eating) dinosaurs, such as the large sauropods (e.g., Diplodocus) and stegosaurs (e.g., Stegosaurus). Carnivorous (flesheating) dinosaurs, such as Compsognathus and Allosaurus, also flourished by hunting the many animals that existed—among them other dinosaurs. Further Jurassic animals included shrewlike mammals, and pterosaurs (flying reptiles), as well as plesiosaurs and ichthyosaurs (both marine reptiles).

JURASSIC POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF JURASSIC PLANT GROUPS



A PRESENT-DAY FERN (Dicksonia antarctica)



A PRESENT-DAY HORSETAIL (Equisetum arvense)



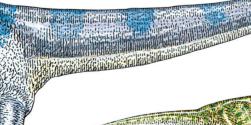
A PRESENT-DAY CONIFER (Taxus baccata)



FOSSIL LEAF OF AN EXTINCT CONIFER (Taxus sp.)



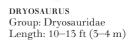
FOSSIL LEAF OF AN EXTINCT REDWOOD (Sequoiadendron affinis)

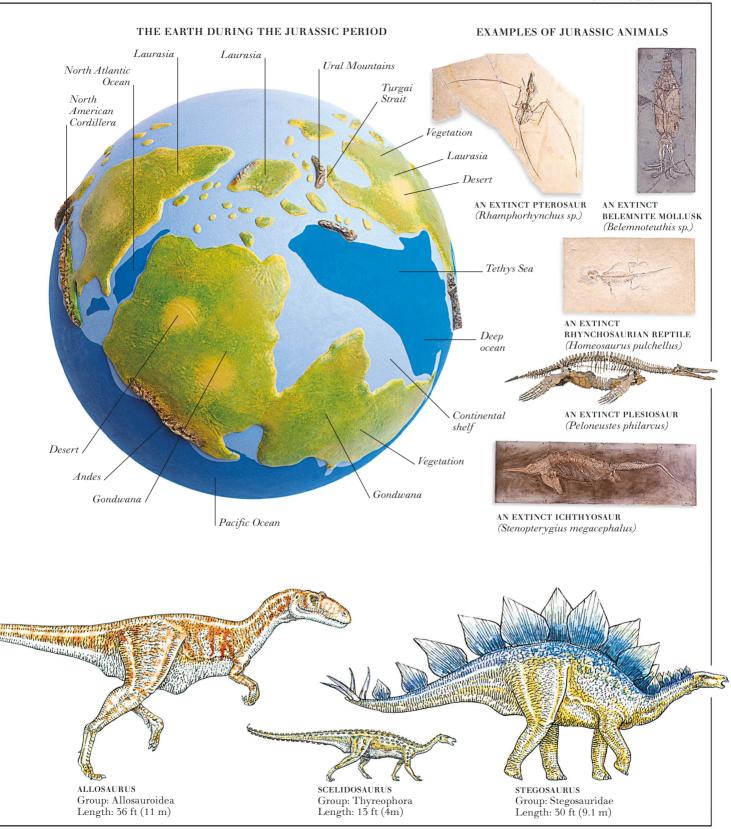


EXAMPLES OF JURASSIC DINOSAURS

DIPLODOCUS Group: Diplodocidae Length: 88 ft (26.8 m)

CAMPTOSAURUS Group: Iguanodontia Length: 16–23 ft (4.9–7 m)

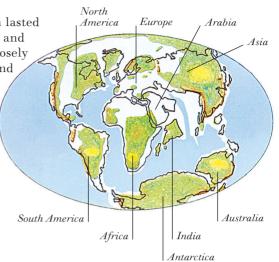




Cretaceous period

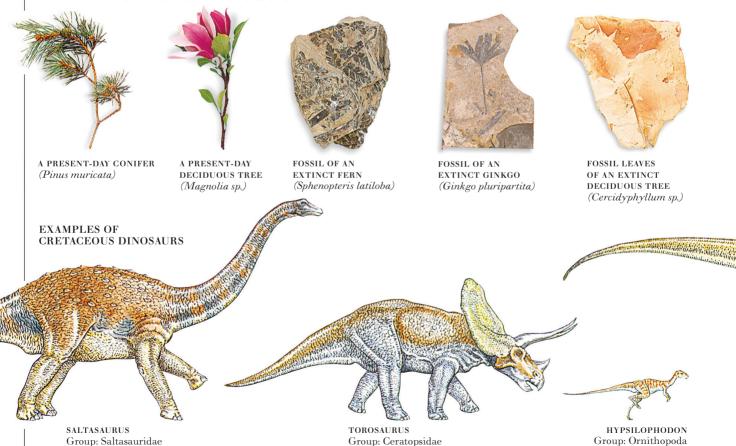
CRETACEOUS POSITIONS OF PRESENT-DAY LANDMASSES

THE MESOZOIC ERA ENDED WITH the Cretaceous period, which lasted from 146 to 65 million years ago. During this period, Gondwana and Laurasia were breaking up into smaller landmasses that more closely resembled the modern continents. The climate remained mild and moist but the seasons became more marked. Flowering plants, including deciduous trees, replaced many cycads, seed ferns, and conifers. Animal species became more varied, with the evolution of new mammals, insects, fish, crustaceans, and turtles. Dinosaurs evolved into a wide variety of species during Cretaceous times; more than half of all known dinosaurs—including Iguanodon, Deinonychus, Tyrannosaurus, and Hypsilophodon—lived during this period. At the end of the Cretaceous period, however, most dinosaurs became extinct. The reason for this mass extinction is unknown but it is thought to have been caused by climatic changes due to either a catastrophic meteor impact with the Earth or extensive volcanic eruptions.



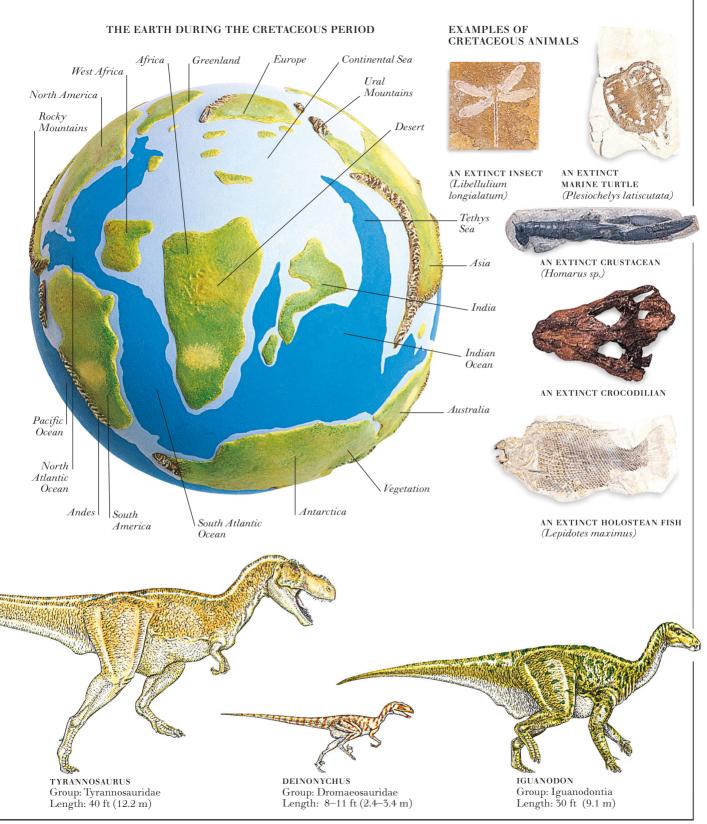
Length: 4 ft 6 in-7 ft 6 in (1.4-2.3 m)

EXAMPLES OF CRETACEOUS PLANT GROUPS



Length: 25 ft (7.6 m)

Length: 40 ft (12.2 m)

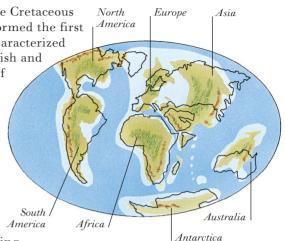


Tertiary period

TERTIARY POSITIONS OF PRESENT-DAY LANDMASSES

FOLLOWING THE DEMISE OF THE DINOSAURS at the end of the Cretaceous period, the Tertiary period (65-1.6 million years ago), which formed the first part of the Cenozoic era (65 million years ago-present), was characterized by a huge expansion of mammal life. Placental mammals nourish and maintain the young in the mother's uterus; only a few groups of placental mammals existed during Cretaceous times, compared with a few dozen during the Tertiary period. One of these included the first hominid (see pp.108–109). Ardipithecus, which appeared in Africa. By the beginning of the Tertiary period, the continents had almost reached their present position. The Tethys Sea, which had separated the northern continents from Africa and India, began to close up, forming the Mediterranean Sea and allowing the migration of terrestrial animals between Africa and western Europe. India's collision with Asia led to the formation of the Himalayas. During the middle part of the Tertiary period, the forest-dwelling

During the middle part of the Tertiary period, the forest-dwelling and browsing mammals were replaced by mammals such as the horses, better suited to grazing the open savannahs that began to dominate. Repeated cool periods throughout the Tertiary period established the Antarctic as an icy island continent.







A PRESENT-DAY OAK (Quercus palustris)



A PRESENT-DAY BIRCH (Betula grossa)



FOSSIL LEAF OF AN EXTINCT BIRCH (Betulites sp.)



FOSSILIZED STEM OF AN EXTINCT PALM (Palmoxylon sp.)

EXAMPLES OF TERTIARY ANIMAL GROUPS



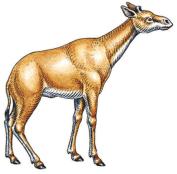
HYAENODON Group: Hyaenodontidae Length: 6 ft 6 in (2 m)



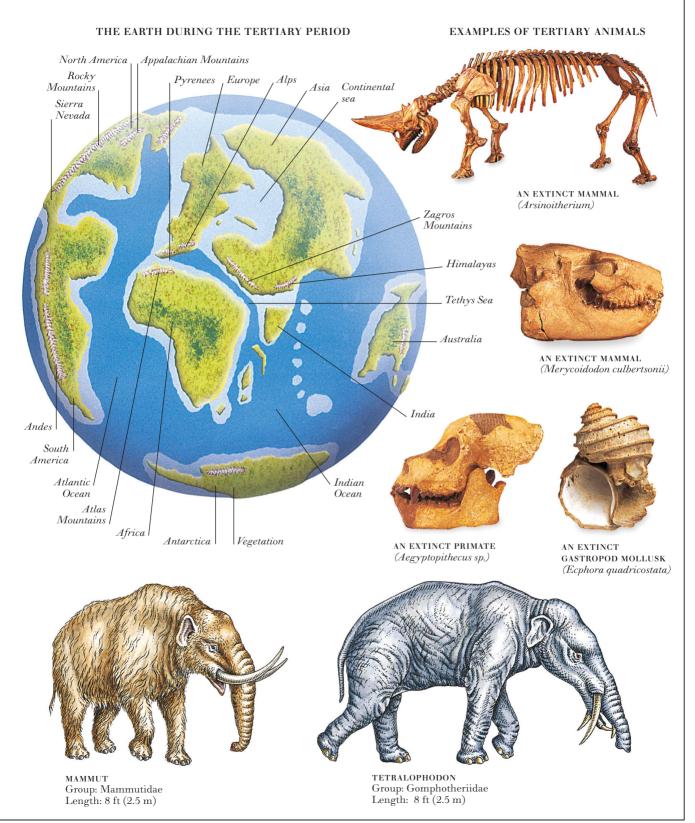
TITANOHYRAX Group: Pliohyracidae Length: 6 ft 6 in (2 m)



PHORUSRHACOS Group: Phorusrhacidae Length: 5 ft (1.5 m)



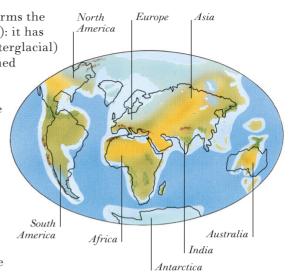
SAMOTHERIUM Group: Giraffidae Length: 10 ft (3 m)



Quaternary period

QUATERNARY POSITIONS OF PRESENT-DAY LANDMASSES

THE OUATERNARY PERIOD (1.6 million years ago-present) forms the second part of the Cenozoic era (65 million years ago-present): it has been characterized by alternating cold (glacial) and warm (interglacial) periods. During cold periods, ice sheets and glaciers have formed repeatedly on northern and southern continents. The cold environments in North America and Eurasia, and to a lesser extent in southern South America and parts of Australia, have caused the migration of many life-forms toward the Equator. Only the specialized ice age mammals such as Mammuthus and Coelodonta, with their thick wool and fat insulation, were suited to life in very cold climates. Humans developed throughout the Pleistocene period (1.6 million-10,000 years ago) in Africa and migrated northward into Europe and Asia. Modern humans, *Homo sapiens*, lived on the cold European continent 30,000 years ago and hunted other mammals. The end of the last ice age and the climatic changes that occurred about 10,000 years ago brought extinction to many Pleistocene mammals, but enabled humans to flourish.



EXAMPLES OF QUATERNARY PLANT GROUPS



A PRESENT-DAY BIRCH (Betula lenta)



A PRESENT-DAY SWEEETGUM (Liquidambar styraciflua)



FOSSIL LEAF OF A SWEETGUM (Liquidambar europeanum)



FOSSIL LEAF OF A BIRCH (Betula sp.)

EXAMPLES OF QUATERNARY ANIMAL GROUPS



PROCOPTODON Group: Macropodidae Length: 10 ft (3 m)



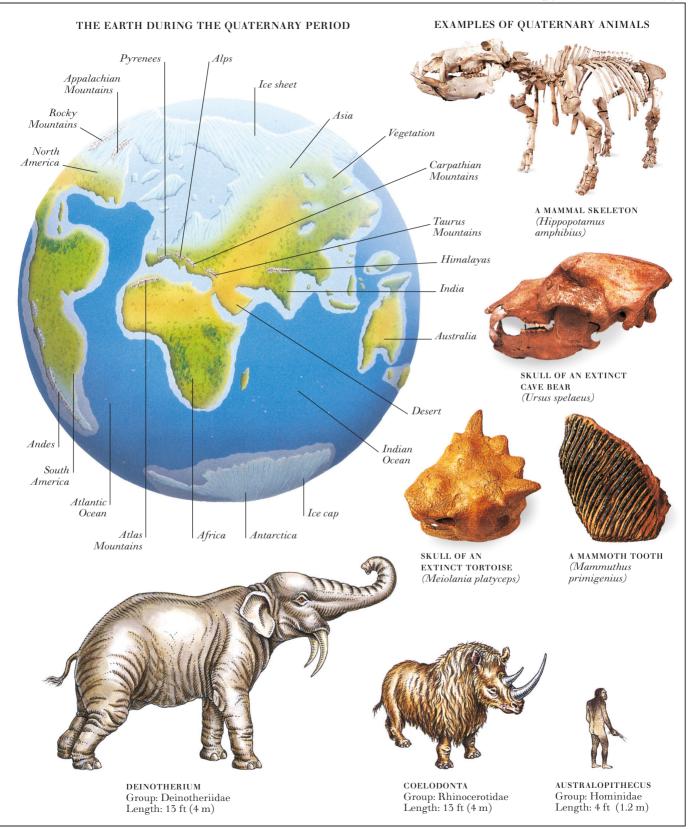
DIPROTODON Group: Diprotodontidae Length: 10 ft (3 m)



TOXODON Group: Toxodontidae Length: 10 ft (3 m)

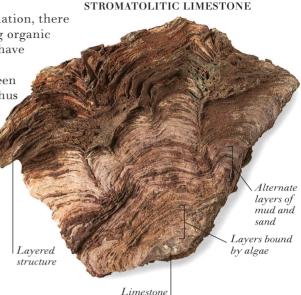


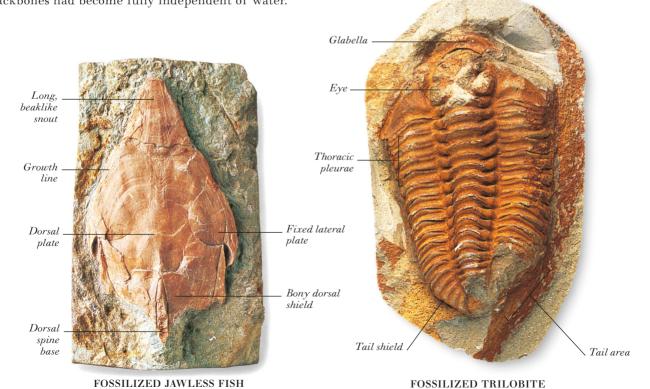
MAMMUTHUS Group: Elephantidae Length: 10 ft (3 m)

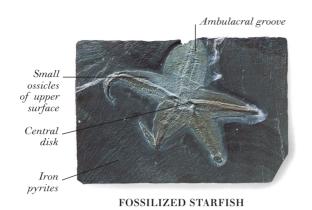


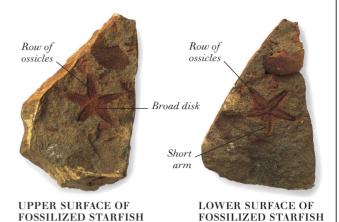
Early signs of life

FOR ALMOST A THOUSAND MILLION YEARS after its formation, there was no known life on Earth. The first simple, sea-dwelling organic structures appeared about 3.5 billion years ago; they may have formed when certain chemical molecules joined together. Prokaryotes, single-celled microorganisms such as blue-green algae, were able to photosynthesize (see pp. 138-139), and thus produce oxygen. A thousand million years later, sufficient oxygen had built up in the Earth's atmosphere to allow multicellular organisms to proliferate in the Precambrian seas (before 570 million years ago). Soft-bodied jellyfish, corals, and seaworms flourished about 700 million years ago. Trilobites, the first animals with hard body frames, developed during the Cambrian period (570-510 million years ago). However, it was not until the beginning of the Devonian period (409–363 million years ago) that early land plants, such as Asteroxylon, formed a waterretaining cuticle, which ended their dependence on an aquatic environment. About 360 million years ago, the first amphibians (see pp. 80-81) crawled onto the land, although they probably still returned to the water to lay their soft eggs. By the time the first reptiles and synapsids appeared late in the Carboniferous, animals with backbones had become fully independent of water.





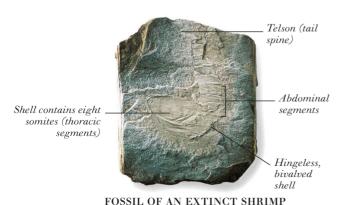




Chelicera Jointed (jointed leg pincer) Jointed leg with oarshaped paddle Segmented abdomen

Growing tip Disk-shaped sporangi'um (spore-case)

UNDERSIDE OF FOSSILIZED EURYPTERID



RECONSTRUCTION OF ASTEROXYLON

Stem

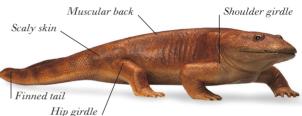
Leaflike scale

Amphibians and reptiles

THE EARLIEST KNOWN AMPHIBIANS, such as Acanthostega and Ichthyostega, lived about 363 million years ago at the end of the Devonian period (409-363 million years ago). Their limbs may have evolved from the muscular fins of lungfishlike creatures. These fish can use their fins to push themselves along the bottom of lakes and some can breathe at the water's surface. While amphibians (see pp. 182–183) can exist on land, they are dependent on a wet environment because their skin does not retain moisture and most species must return to the water to lay their eggs. Evolving from amphibians, reptiles (see pp. 184–187) first appeared during the Carboniferous period (363–290 million years ago): Westlothiana, a possible early reptile, lived on land 338 million years ago. The development of the amniotic egg, with an embryo enclosed in its own wet environment (the amnion) and protected by a waterproof shell, freed reptiles from the amphibian's dependence on a wet habitat. A scaly skin protected the reptile from desiccation on land and enabled it to exploit ways of life closed to its amphibian ancestors. Reptiles include the dinosaurs, which came to dominate life on land during the Mesozoic era (245–65 million years ago).



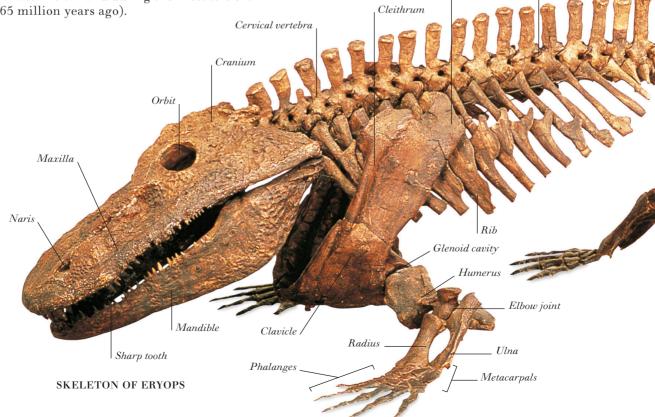
FOSSIL SKULL OF ACANTHOSTEGA

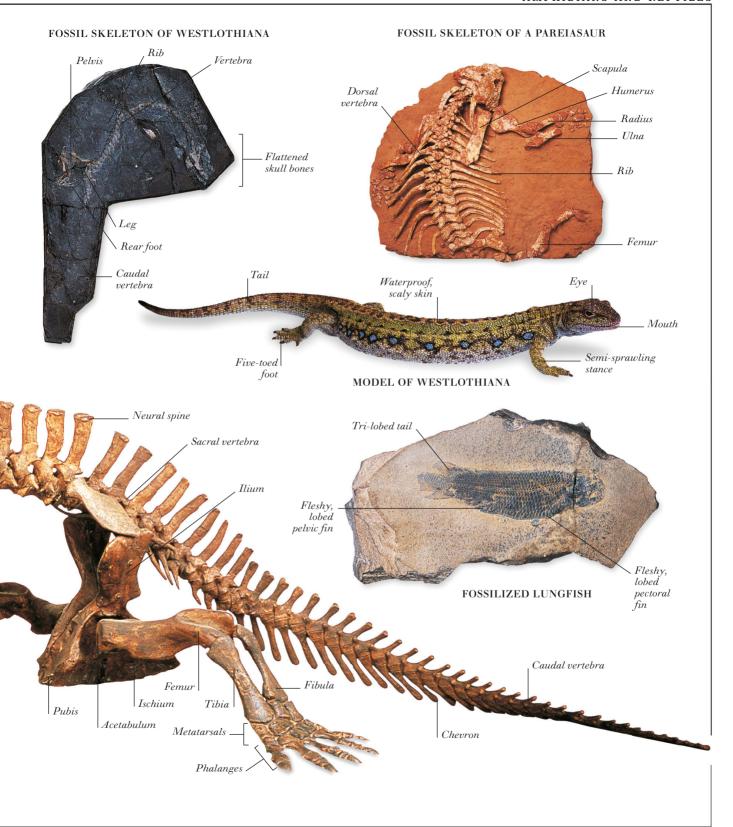


MODEL OF ICHTHYOSTEGA

Scapula

Dorsal vertebra





The dinosaurs

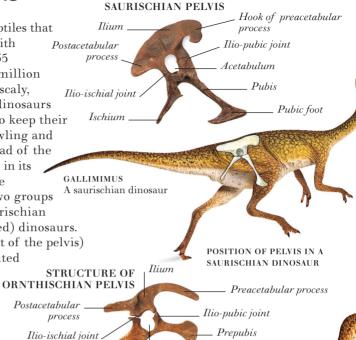
THE DINOSAURS WERE A LARGE GROUP of reptiles that were the dominant land vertebrates (animals with backbones) for most of the Mesozoic era (245-65 million years ago). They appeared some 230 million years ago and were distinguished from other scaly, egg-laying reptiles by an important feature: dinosaurs had an erect limb stance. This enabled them to keep their bodies well above the ground, unlike the sprawling and semisprawling stance of other reptiles. The head of the dinosaur's femur (thighbone) fit into a socket in its pelvis (hip-bone), producing efficient and mobile locomotion. Dinosaurs are categorized into two groups according to the structure of their pelvis: saurischian (lizard-hipped) and ornithischian (bird-hipped) dinosaurs. In the case of most saurischians, the pubis (part of the pelvis) jutted forward, while in ornithischians it slanted back, parallel to the ischium (another part of

from smaller than a domestic cat

from smaller than a domestic cat

to the biggest land animals ever
known. The Dinosauria

were the most successful land
vertebrates ever, and survived
for 165 million years, until
most became extinct
65 million years ago.



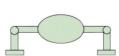
Acetabulum

POSITION OF PELVIS IN AN

ORNITHISCHIAN DINOSAUR

STRUCTURE OF





SPRAWLING STANCE
The thighs and upper arms
project straight out from the
body so that the knees and
elbows are bent at right angles.



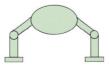
COMMON IGUANA (*Iguana iguana*) A present-day reptile

HYPSILOPHODON An ornithischian dinosaur



BAROSAURUS A saurischian dinosaur

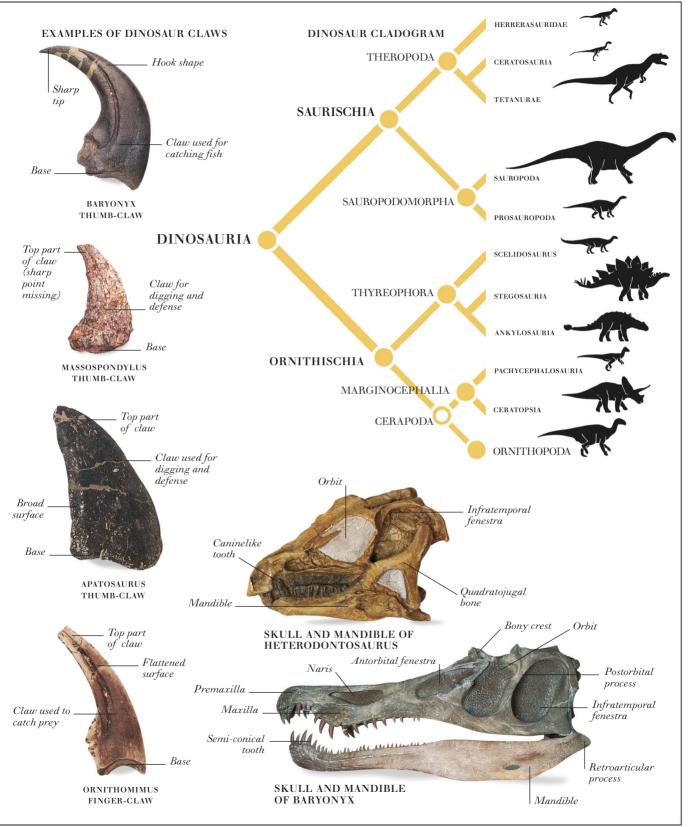
ERECT STANCE
The thighs and upper arms
project straight down from
the body so that the knees
and elbows are straight.



SEMISPRAWLING STANCE The thighs and upper arms project downwards and outwards so that the knees and elbows are slightly bent.

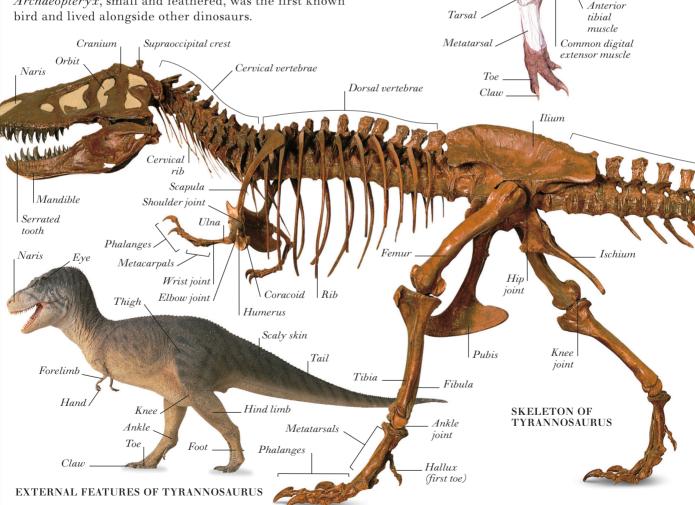


DWARF CROCODILE (Osteolaemus tetraspis) A present-day reptile



Theropods 1

AN ENORMOUSLY SUCCESSFUL SUBGROUP of the Saurischia. the bipedal (two-footed) theropods ("beast feet") emerged 230 million years ago in Late Triassic times; the oldest known example comes from South America. Theropods spanned the age of most dinosaurs (230-65 million years ago) and beyond, and included most of the known predatory dinosaurs. The typical theropod had smallish arms with sharp, clawed fingers; powerful jaws lined with sharp teeth; an S-shaped neck; long, muscular hind limbs; and clawed, usually four-toed feet. Many theropods may have been warm-blooded; most were exclusively carnivorous. Theropods ranged from animals no larger than a chicken to huge creatures, such as Tyrannosaurus and Baryonyx. The group also included ostrichlike omnivores and herbivores with toothless beaks, such as Struthiomimus and Gallimimus. Birds are dinosaurs and evolved from within a group of tetanuran theropods called maniraptorans. Archaeopteryx, small and feathered, was the first known bird and lived alongside other dinosaurs.



Ilio-tibial muscle
Ilio-femoral muscle

Ambiens

muscle

Femoro-

tibial

muscle

INTERNAL ANATOMY OF

Femoro-tibial

Internal tibial

flexor muscle

muscle

Femur

muscle

muscle

Ilio-fibular

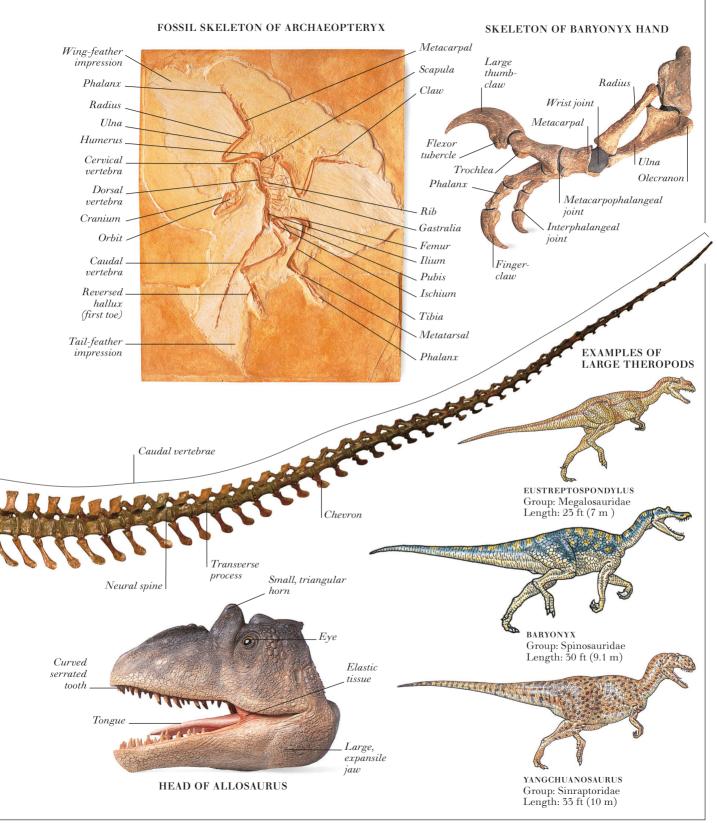
Gastrocnemius

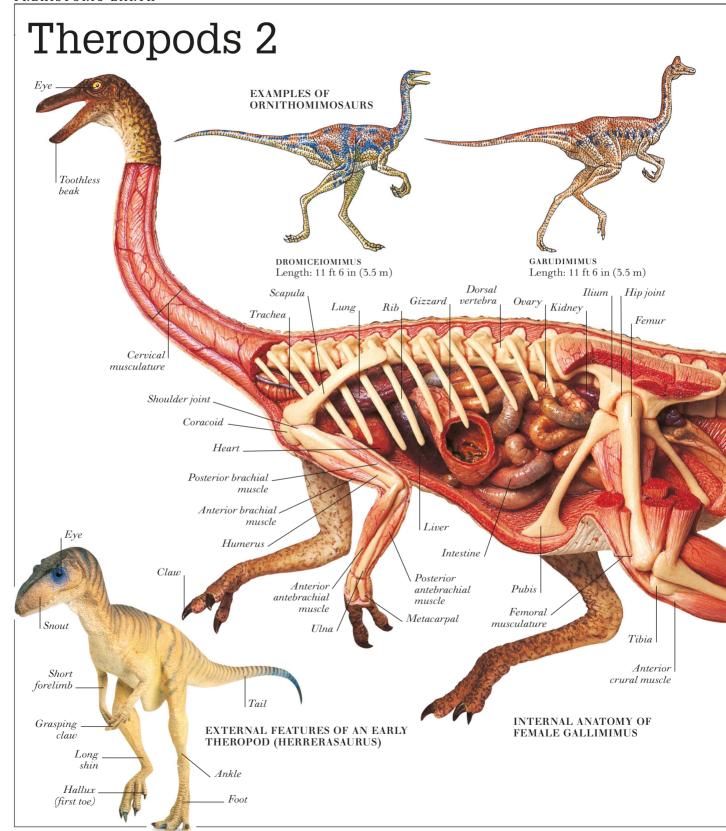
muscle

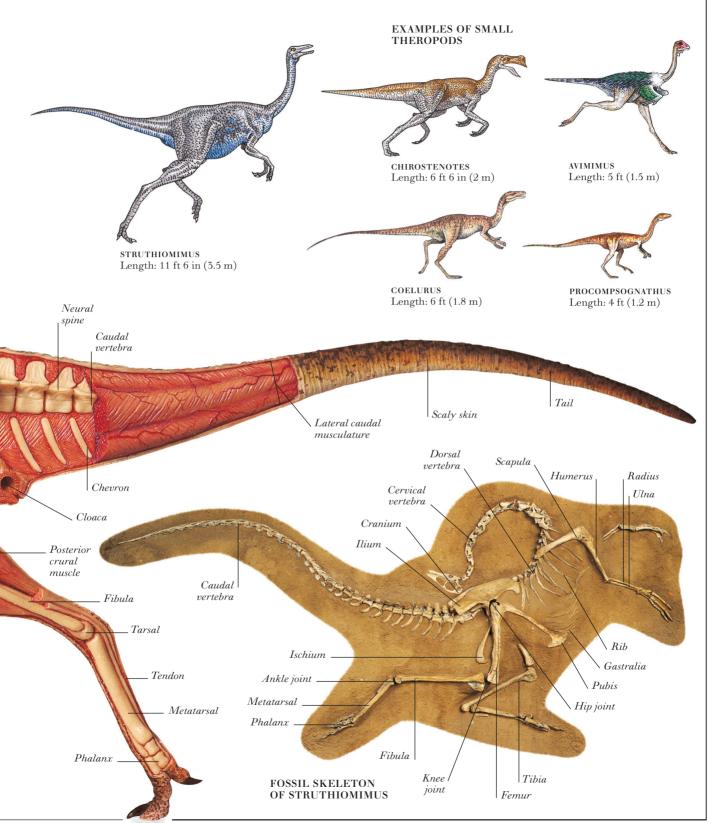
Digital flexor

Fibula

ALBERTOSAURUS LEG







Sauropodomorphs 1

SKULL AND MANDIBLE OF **PLATEOSAURUS**

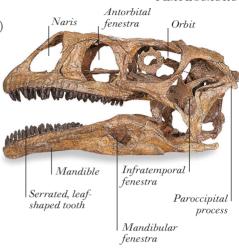
Sacral vertebrae

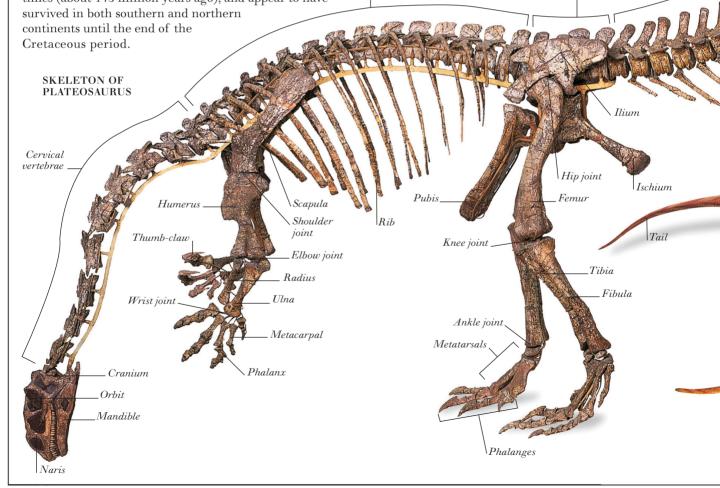


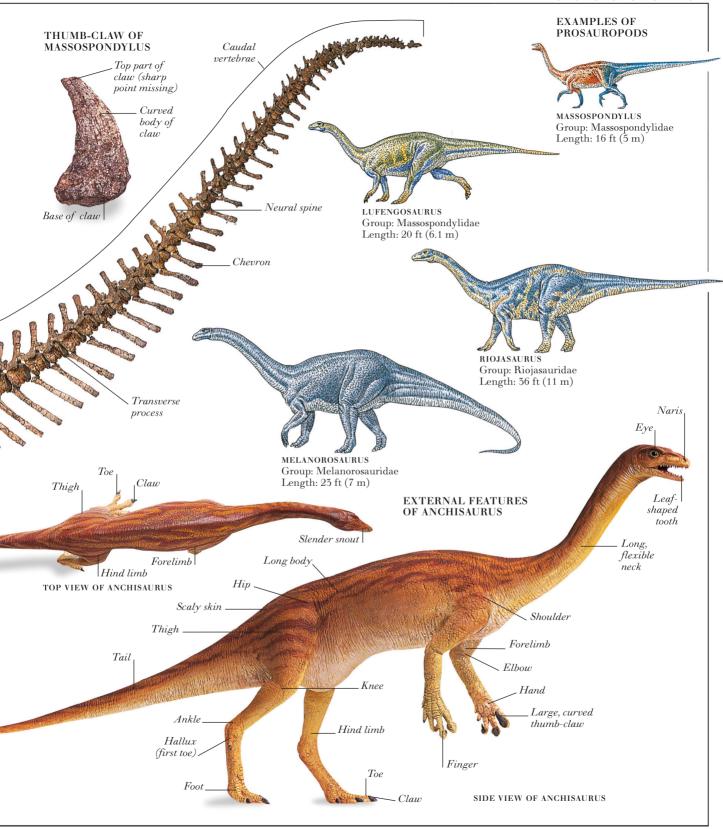
THE SAUROPODOMORPHA ("lizard-feet forms") were herbivorous, usually quadrupedal (four-footed) dinosaurs. A suborder of the Saurischia, they were characterized by small heads, bulky bodies, and long necks and tails. Sauropodomorphs have often been split into two groups: prosauropods and

THECODONTOSAURUS

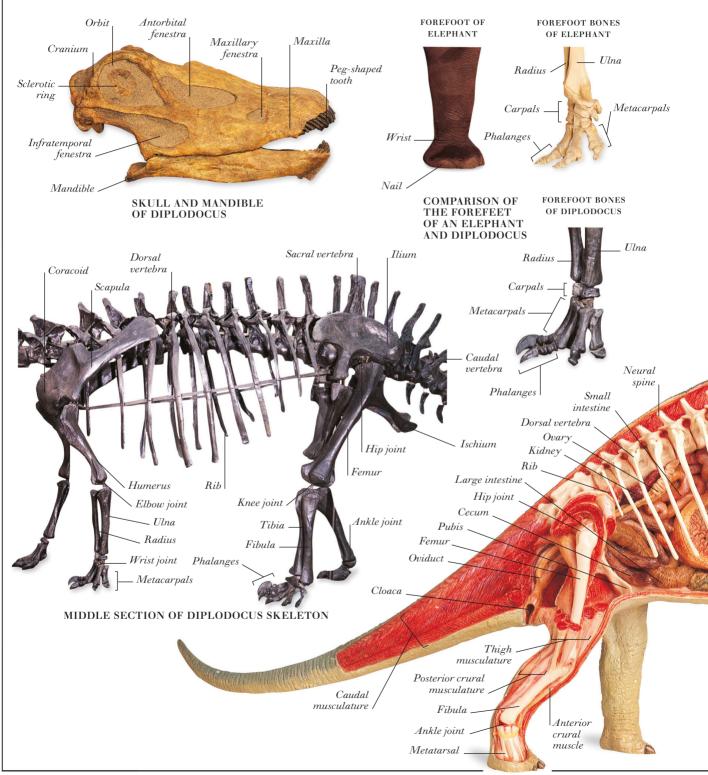
sauropods. Prosauropods lived from Late Triassic to Early Jurassic times (225–180 million years ago) and included beasts such as the small *Anchisaurus* and one of the first very large dinosaurs, Plateosaurus. By Middle Jurassic times (about 165 million years ago), sauropods had replaced prosauropods and spread worldwide. They included the heaviest and longest land animals ever, such as Diplodocus and Brachiosaurus. Sauropods persisted to the end of the Cretaceous period (65 million years ago). Many of these dinosaurs moved in herds, protected from predatory theropods by their huge bulk and powerful tails, which they could use to lash out at attackers. Sauropodomorphs were the most common large herbivores until Late Jurassic Dorsal vertebrae times (about 145 million years ago), and appear to have

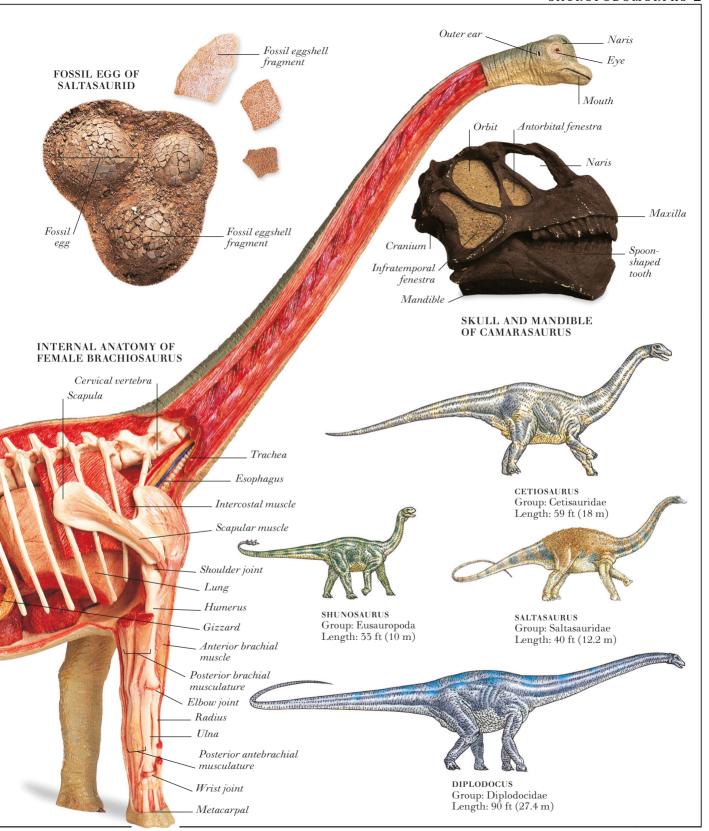


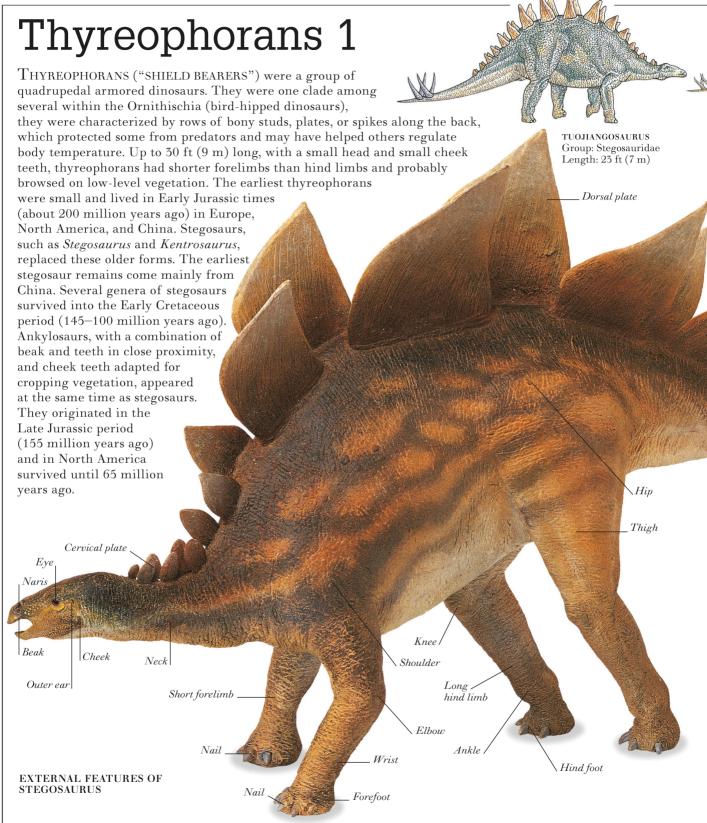


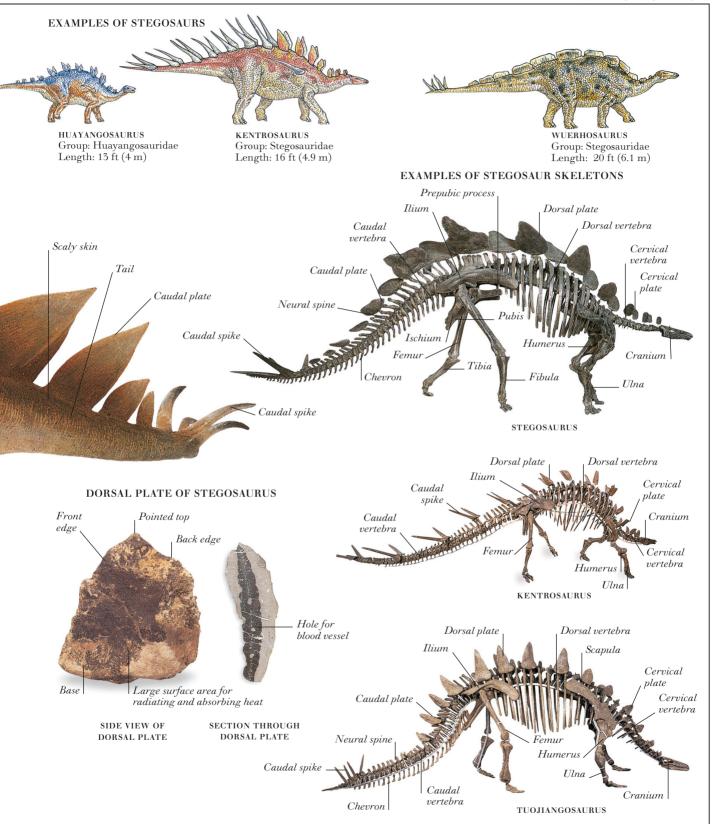


Sauropodomorphs 2

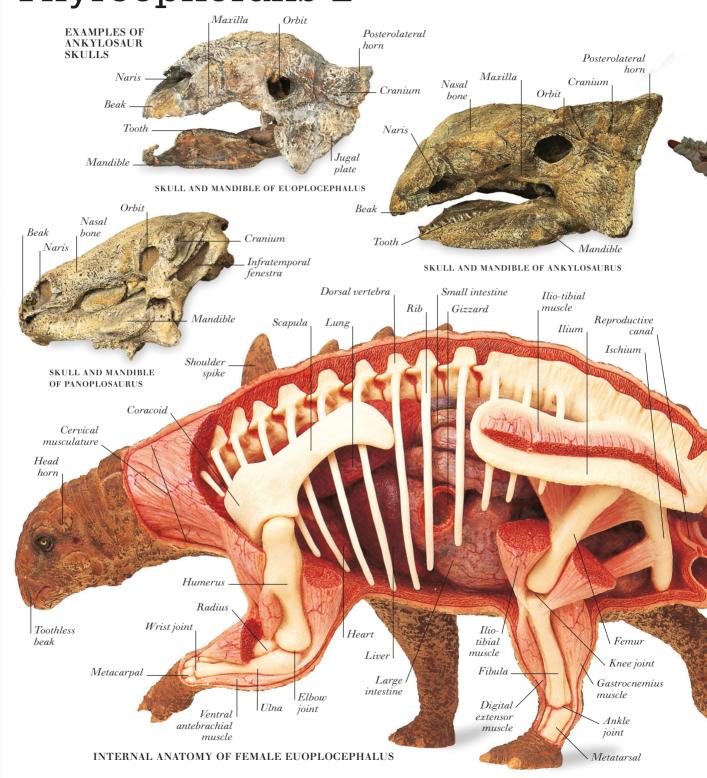


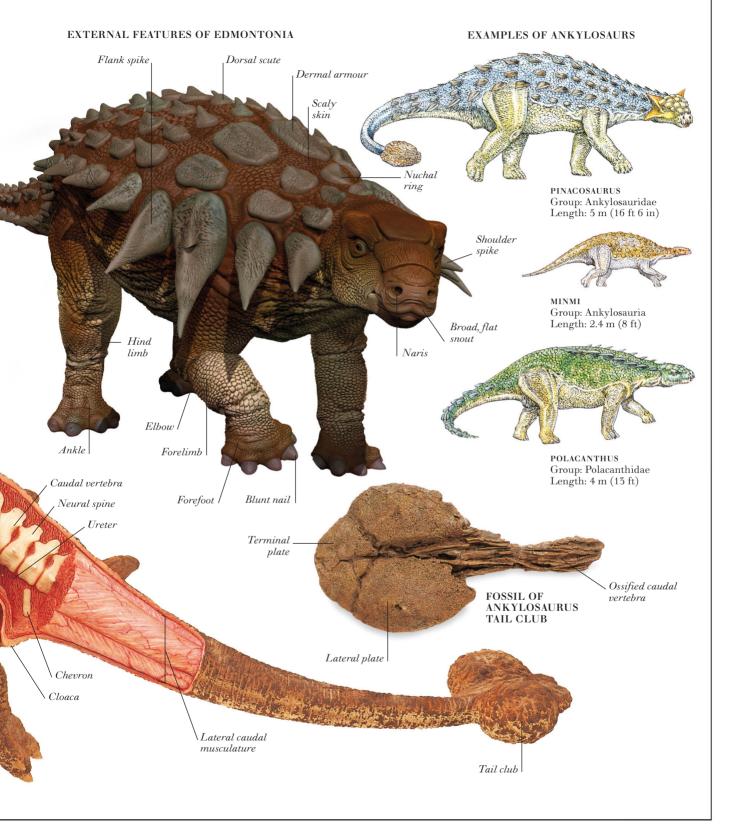






Thyreophorans 2





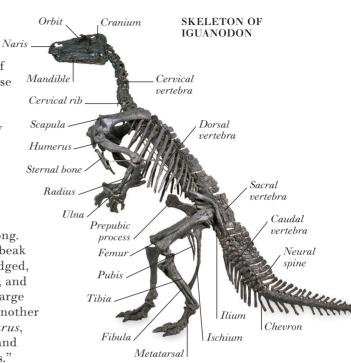
Ornithopods 1



IGUANODON TOOTH

ORNITHOPODS ("BIRD FEET") were a group of ornithischian ("bird-hipped") dinosaurs. These bipedal and quadrupedal herbivores had a horny beak, plant-cutting or grinding cheek teeth, and a pelvic and tail region stiffened by bony tendons. They evolved teeth and jaws adapted to pulping vegetation and flourished from the Middle Jurassic to the Late

Cretaceous period (165–65 million years ago) in North America, Europe, Africa, China, Australia, and Antarctica. Some ornithopods were no larger than a dog, while others were immense creatures up to 49 ft (15 m) long. Iguanodonts, an ornithopod group, had a broad, toothless beak at the end of a long snout, large jaws with long rows of ridged, closely packed teeth for grinding vegetation, a bulky body, and a heavy tail. *Iguanodon* and some other iguanodonts had large thumb-spikes that were strong enough to stab attackers. Another group, the hadrosaurs, such as *Gryposaurus* and *Hadrosaurus*, lived in Late Cretaceous times (97–65 million years ago) and with their broad beaks are sometimes known as "duckbills." They were characterized by their deep skulls and closely packed rows of teeth, while some, such as *Corythosaurus* and *Lambeosaurus*, had tall, hollow, bony head crests.



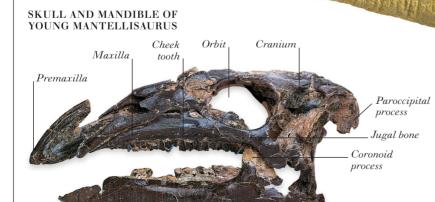
Thigh



Predentary

bone

Heavy, stiff tail



Dentary

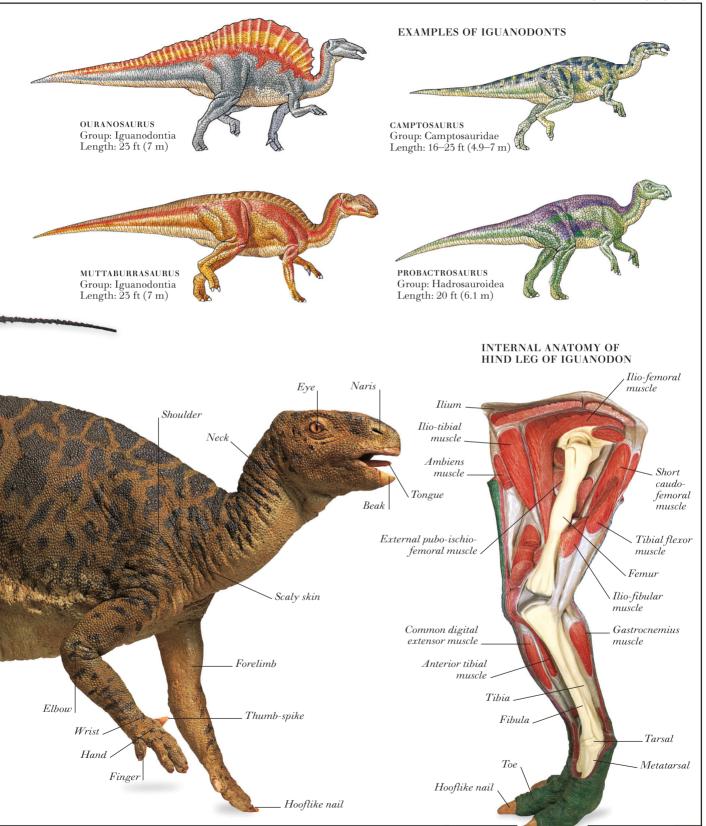
hone

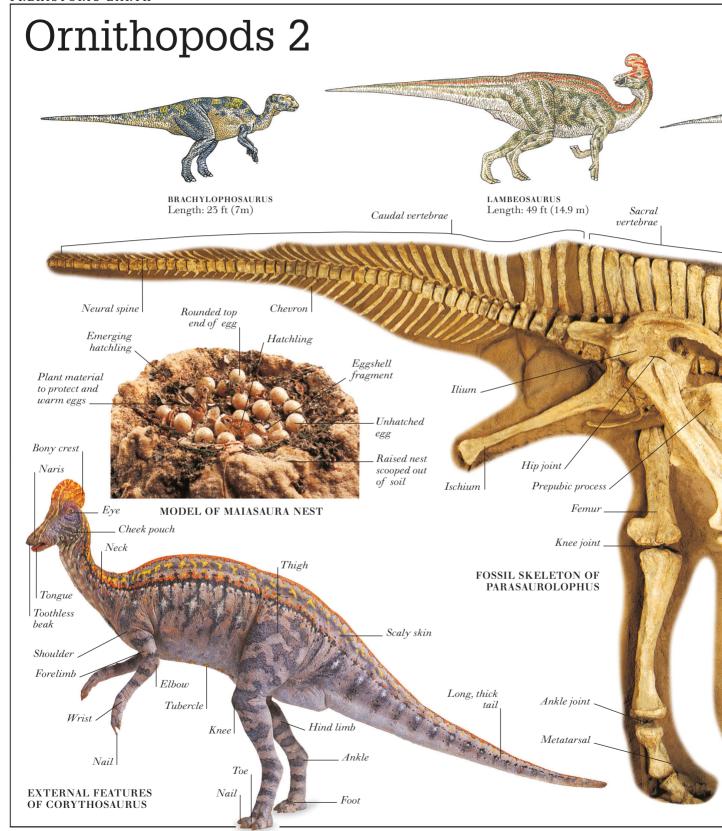
Mandible

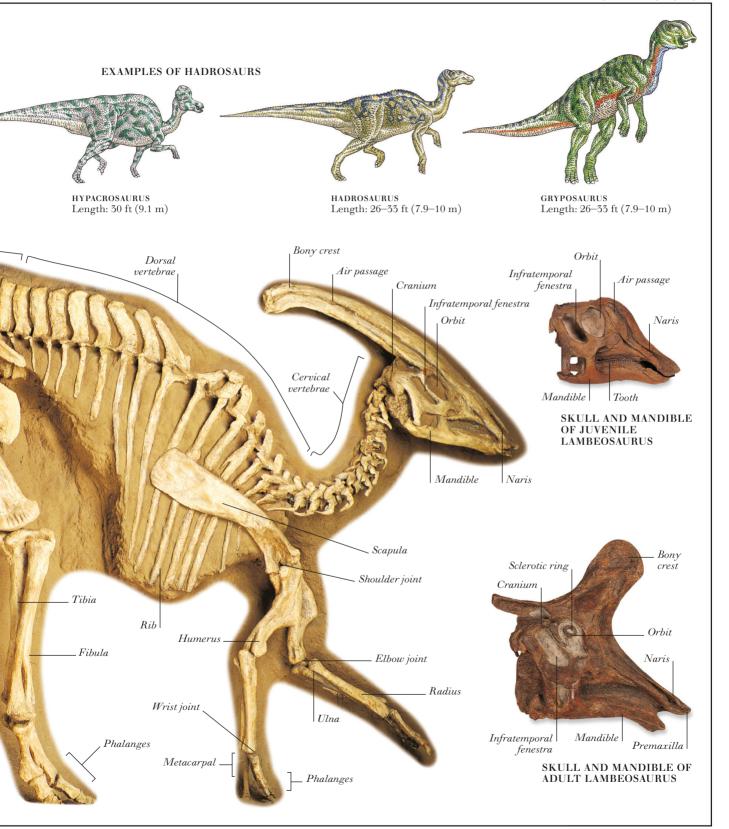




 $Hoof like\ nail$





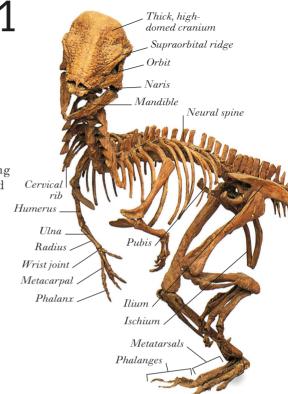


HEAD-BUTTING PRENOCEPHALES

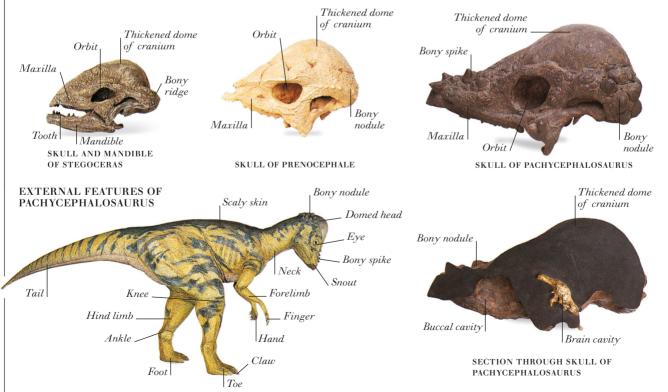
Marginocephalians 1

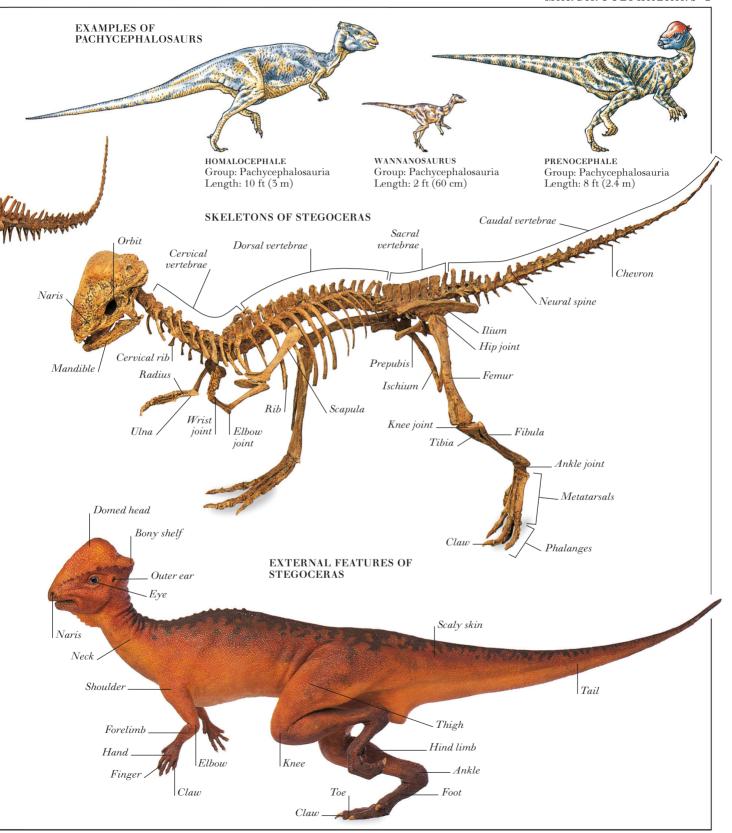
Marginocephalia ("margined heads") were a group of bipedal and quadrupedal ornithischian dinosaurs with a narrow shelf or deep, bony frill at the back of the skull. Marginocephalians were

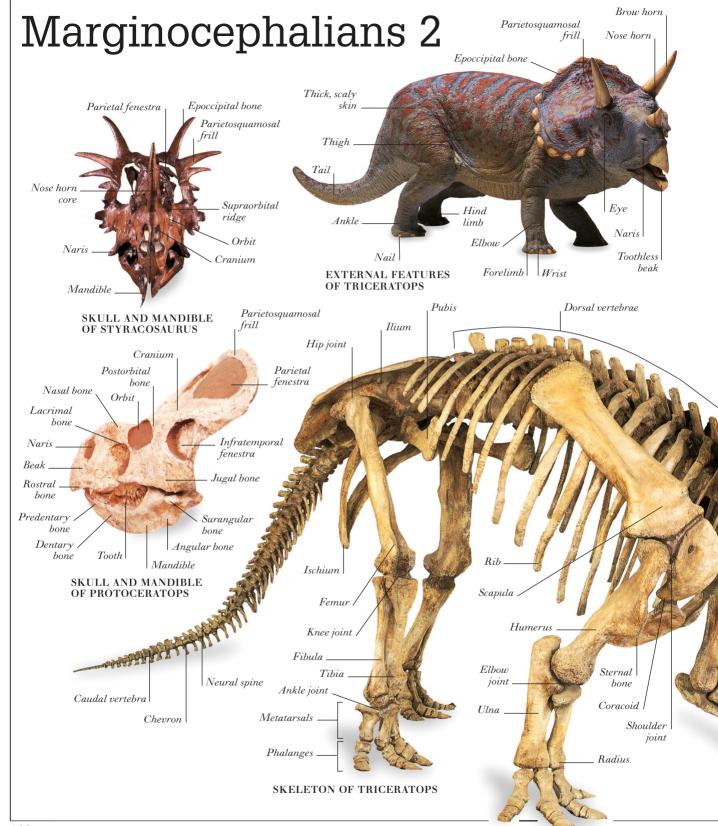
probably descended from the same ancestor as the ornithopods and lived in what are now North America, Africa, Asia, and Europe during the Cretaceous period (145-65 million years ago). They were divided into two groups: Pachycephalosauria ("thick-headed lizards"), such as Pachycephalosaurus and Stegoceras, and Ceratopsia ("horned faces"), such as Triceratops and Psittacosaurus. The thick skulls of Pachycephalosauria may have protected their brains during possible head-butting contests fought to win territory and mates; their hips and spines may also have been strengthened to withstand the shock. The bony frill of Ceratopsia would have added to their frightening appearance when charging; the neck was strengthened for impact and to support the huge head, with its snipping beak and powerful slicing toothed jaws. A charging ceratopsian would have been a formidable opponent for even the largest predators. Ceratopsians were among the most abundant herbivorous dinosaurs of the Late Cretaceous period (97-65 million years ago).

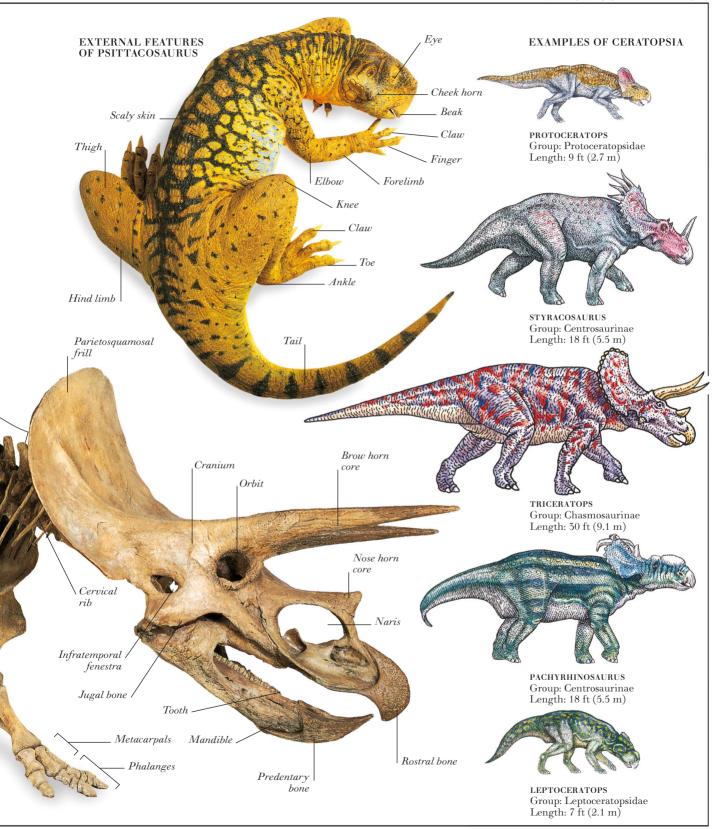


EXAMPLES OF SKULLS OF PACHYCEPHALOSAURS









Mammals 1

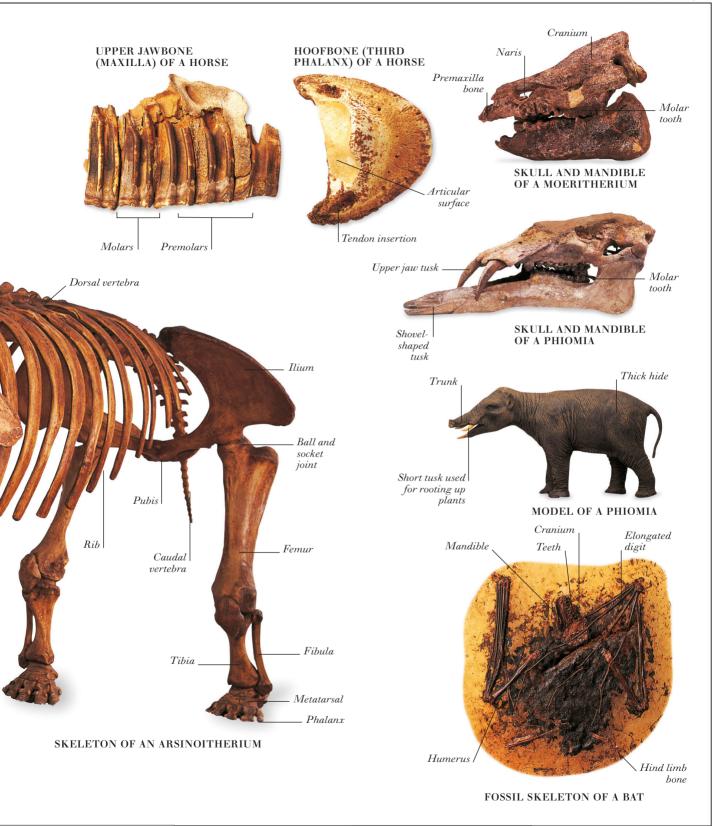


TETRALOPHODON CHEEK TEETH

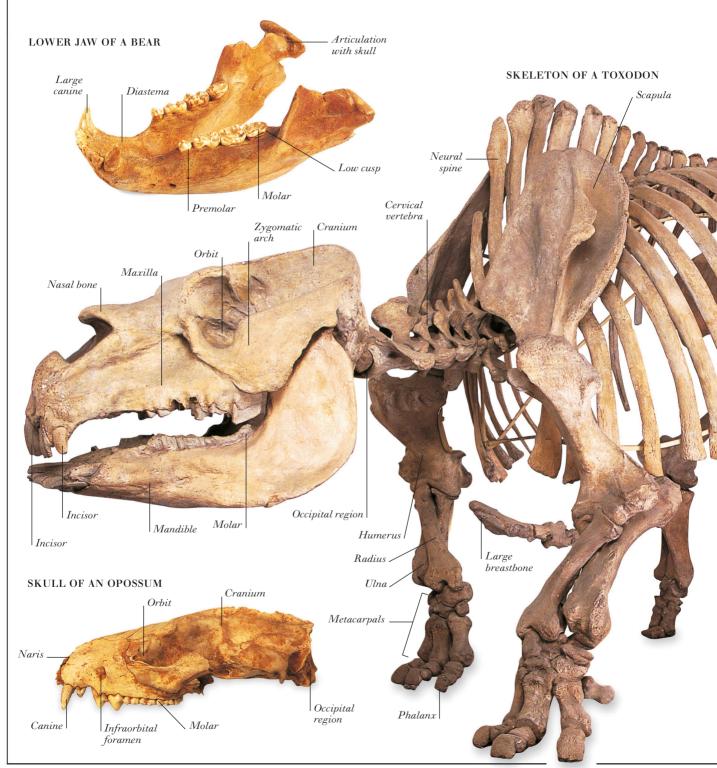
SINCE THE EXTINCTION of most of the dinosaurs 65 million years ago, mammals (along with birds) have been the dominant vertebrates on land. This class includes terrestrial, aerial, and aquatic forms. Having developed from the therapsids, the first true mammals—small, nocturnal, shrewlike creatures, such as Megazostrodon-appeared over 200 million years ago during the Triassic period

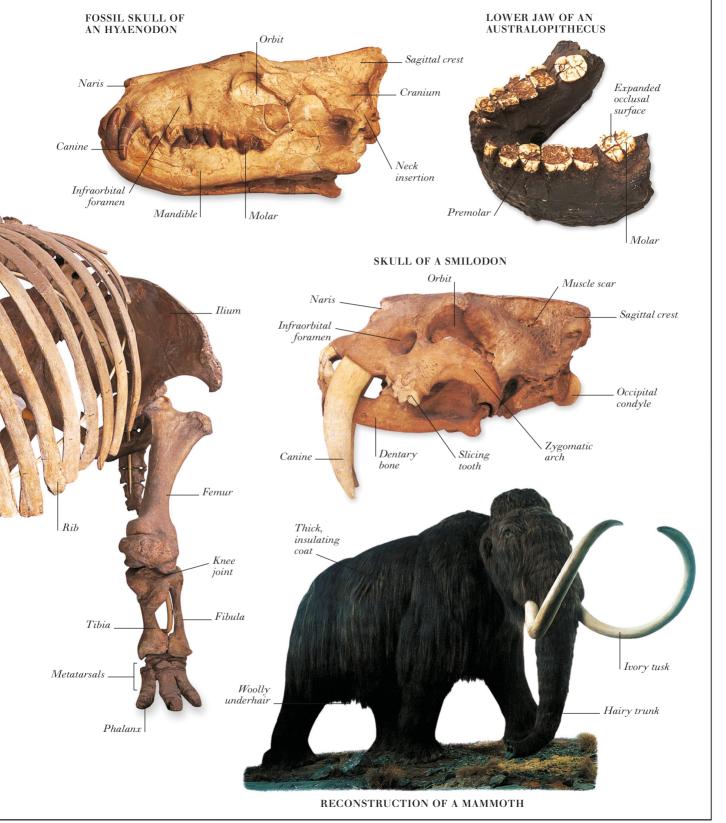
MODEL OF A

(250-200 million years ago). Mammals had several features that differed from those of their ancestors: an efficient four-chambered heart allowed these warm-blooded animals Insulating balance to sustain high levels of activity; a covering of hair helped them maintain a constant body temperature; an improved limb structure gave them more efficient locomotion; and the birth of live young and the immediate supply of food from the mother's milk aided their rapid growth. Since the end of the Mesozoic era (65 million years ago), the Neural number of major mammal groups and the abundance of species in each spine have varied dramatically. For example, the Perissodactyla (the group Scapula that includes Coelodonta and modern horses) was a common group during the Early Tertiary period (about 54 million years ago). Cervical vertebra Today, the mammalian groups with the most species include the Rodentia (rats and mice), the Chiroptera (bats), the Primates (monkeys and apes), the Carnivora (bears, cats, and dogs), and the Artiodactyla (cattle, deer, and pigs), while the Proboscidea group, which formerly included many genera, such as Phiomia, Moeritherium, Tetralophodon, and Mammuthus, now has only three species of elephant. In Australia and South America, millions of years of continental isolation led to increased diversity of the marsupials, a group of mammals distinct from the placentals (see p. 74) that existed elsewhere. Humerus Nasal horn Naris Orbit Radius Mandible Premaxilla bone Ulna Chisel-edged molar Metacarpal Phalanx _



Mammals 2





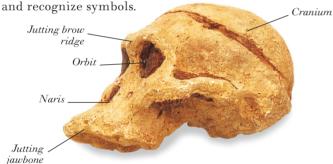
The first humans

MODERN HUMANS BELONG TO THE MAMMALIAN order of primates (see pp. 202–203), which originated about 55 million years ago; primates included the only extant hominid species. The earliest hominid was Ardipithecus ("ground ape") and Australopithecus ("southern ape"), both small-brained intermediates between apes and humans that were capable of standing and walking upright. Homo habilis, the earliest member of the genus Homo, appeared at least 2 million years ago. This larger-brained "handy man" began making tools for hunting. Homo ergaster first appeared in Africa about 1.8 million years ago and spread into Asia about 800,000 years later. Smaller-toothed than Homo habilis, H. ergaster—followed by Homo erectus—developed fire as a tool, which enabled it to cook food. Neanderthals, a near relative of modern humans, originated about 200,000 years ago, and Homo sapiens (modern humans) appeared in Africa about

Homo sapiens had become dominant and the Neanderthals had died out. Classification of Homo sapiens in relation to its ancestors is enormously problematic: modern humans must be classified not only by bone structure, but also by specific behavior—the ability to plan future action: to follow traditions: and to use

100,000 years later. The two coexisted for thousands of years, but by 30,000 years ago,

behavior—the ability to plan future action; to follow traditions; and to use symbolic communication, including complex language and the ability to use



SKULL OF AUSTRALOPITHECUS (SOUTHERN APE)



JAWBONE OF AUSTRALOPITHECUS

Larger jawbone than modern

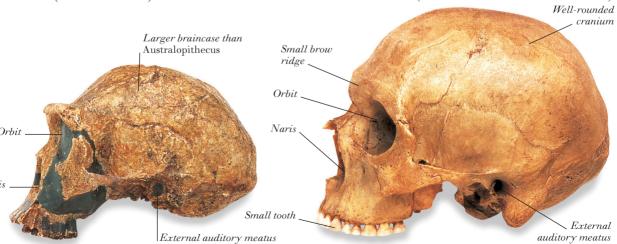
Large back

tooth

human

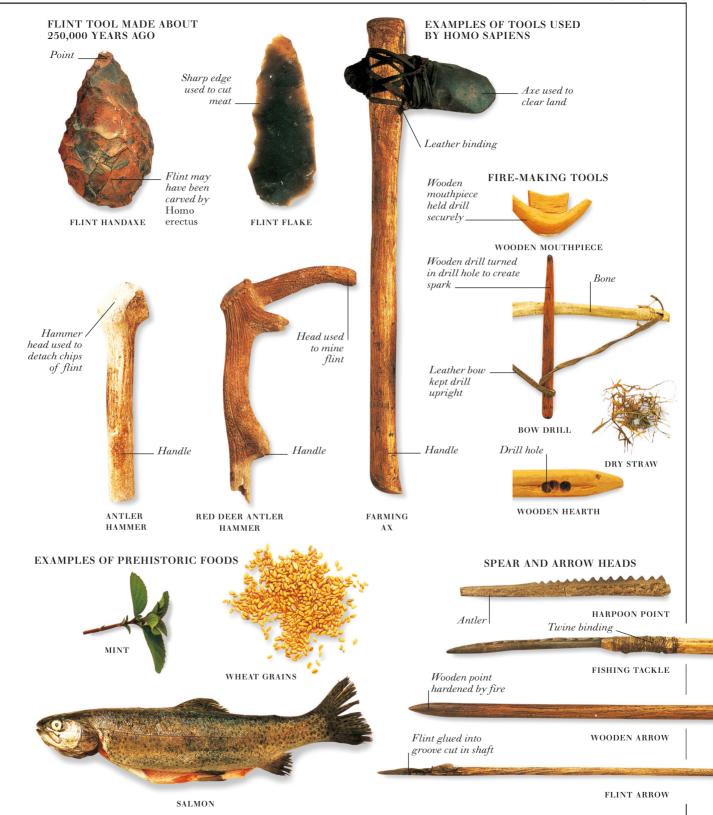
(SOUTHERN APE)

SKULL OF HOMO HABILIS (FIRST MEMBER OF HOMO GENUS)



SKULL OF HOMO ERECTUS (UPRIGHT MAN)

SKULL OF HOMO SAPIENS (MODERN HUMAN)







PLANTS

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Plant varieties

FLOWERING PLANT

Bromeliad (Acanthostachys strobilacea)

Leaf

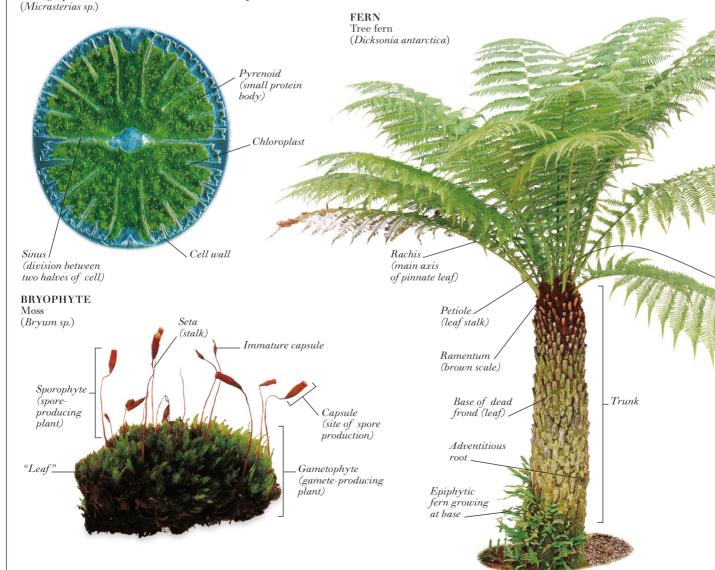
There are more than 300,000 species of plant.

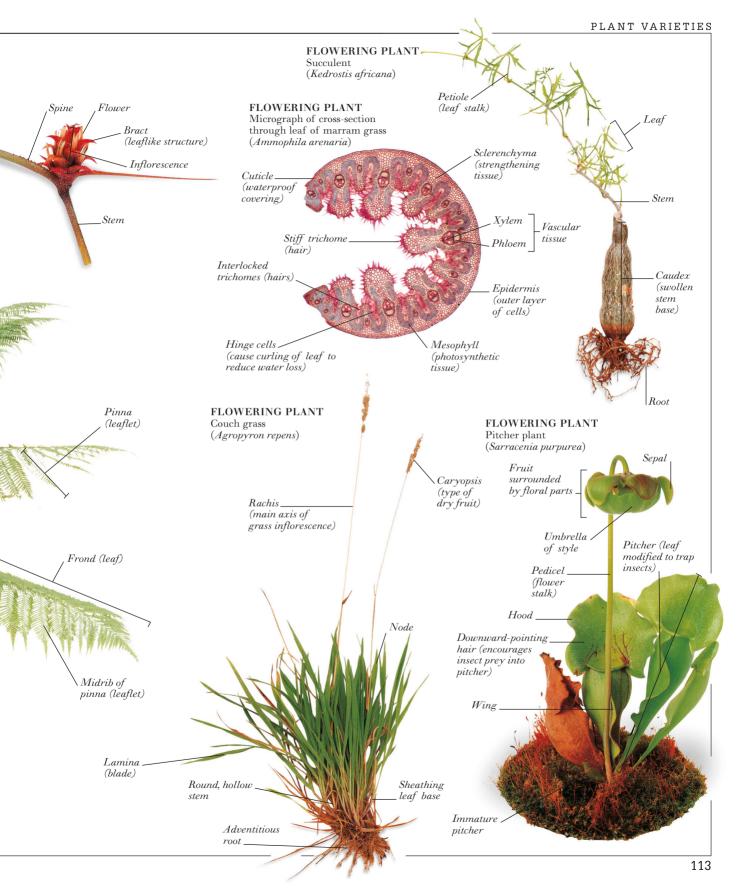
They show a wide diversity of forms and life-styles, ranging, for example,

from delicate liverworts, adapted for life in a damp habitat, to cacti, capable of surviving in the desert, and from herbaceous plants, such as corn, which completes its life-cycle in one year, to the giant redwood tree, which can live for thousands of years. This diversity reflects the adaptations of plants to survive in a wide range of habitats. This is seen most clearly in the flowering plants (phylum Angiospermophyta), which are the most numerous, with over 250,000 species, and the most widespread, being found from the tropics to the poles. Despite their diversity, plants share certain characteristics: typically, plants are green, and make their food by photosynthesis; and most plants live in or on a substrate, such as soil, and do not actively move. Algae (kingdom Protista) and fungi (kingdom Fungi) have

GREEN ALGA
Micrograph of desmid

son, and do not actively move. Argae (kingdom Frotista) and rungi (kin





EXAMPLES OF FUNGI

Emerging

sporophore

(spore-bearing structure)

Pileus (cap)

stipe (stalk)

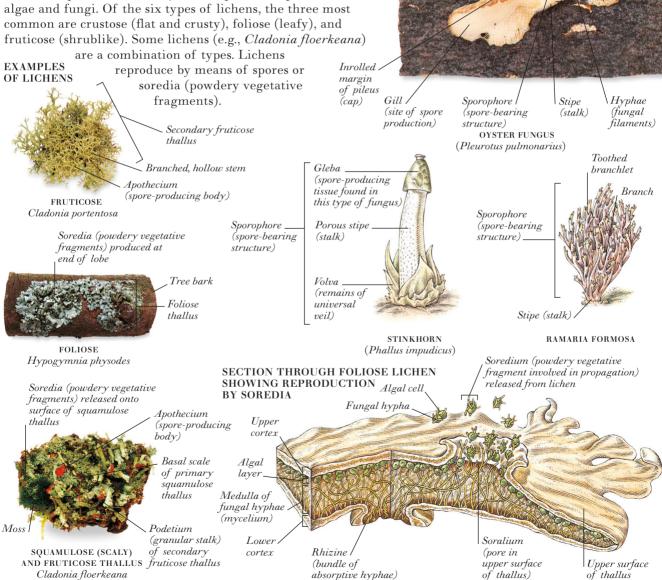
continuous with

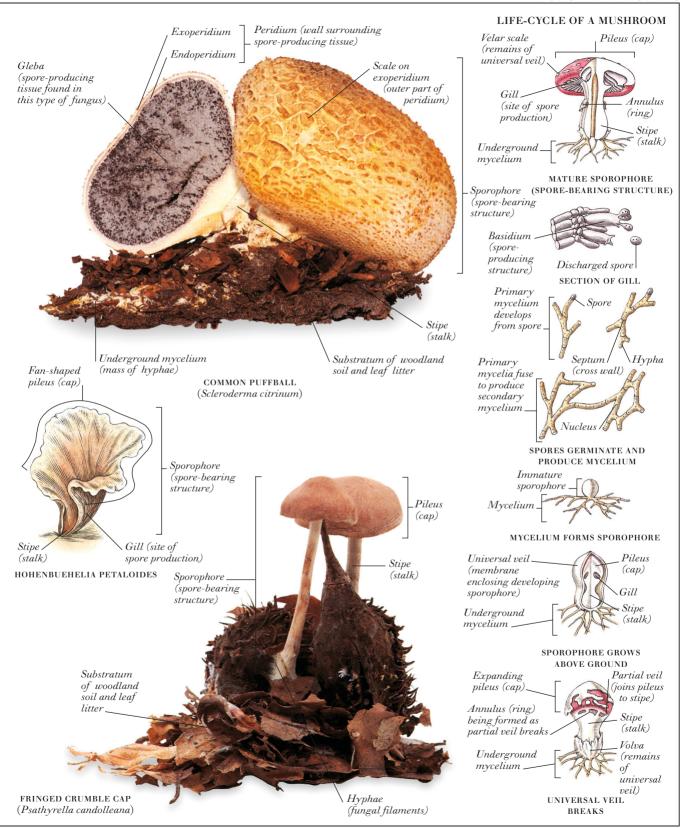
Bark

of dead beech tree

Fungi and lichens

Fungi were once thought of as plants but are now classified as a separate kingdom. This kingdom includes not only the familiar mushrooms, puffballs, stinkhorns, and molds, but also yeasts, smuts, rusts, and lichens. Most fungi are multicellular, consisting of a mass of threadlike hyphae that together form a mycelium. However, the simpler fungi (e.g., yeasts) are microscopic, single-celled organisms. Typically, fungi reproduce by means of spores. Most fungi feed on dead or decaying matter, or on living organisms. A few fungi obtain their food from plants or algae, with which they have a symbiotic (mutually advantageous) relationship. Lichens are a symbiotic partnership between algae and fungi. Of the six types of lichens, the three most common are crustose (flat and crusty), foliose (leafy), and fruticose (shrublike). Some lichens (e.g., Cladonia floerkeana)



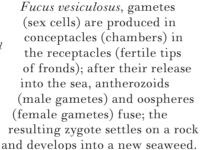


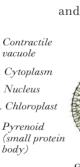
Algae and seaweeds

ALGAE ARE NOT TRUE PLANTS. They form a diverse group of plantlike organisms that belong to the kingdom Protista. Like plants, algae possess the green pigment chlorophyll and make their own food by photosynthesis (see pp. 138-139). Many algae also possess other pigments by which they can be classified; for example, the brown pigment fucoxanthin is found in the brown algae. Some of the 10 phyla of algae are exclusively unicellular (single-celled); others also contain aggregates of cells in filaments or colonies. Three phyla the Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae)—contain larger, multicellular, thalloid (flat), marine organisms commonly known as seaweeds.

Most algae can reproduce sexually. For

example, in the brown seaweed Fucus vesiculosus, gametes (sex cells) are produced in conceptacles (chambers) in the receptacles (fertile tips of fronds); after their release into the sea, antherozoids (male gametes) and oospheres





grain GREEN ALGA Chlamydomonas sp.

GREEN ALGA

Acetabularia sp.

Flagellum

EXAMPLES OF ALGAE

Stalk

Eyespot

Cell

wall

Starch

Reproductive

Sterile whorl

chamber

Cell wall

Rhizoid

BROWN SEAWEED Oarweed

Daughter coenobium Girdle Gelatinous sheath Biflagellate cell GREEN ALGA DIATOM

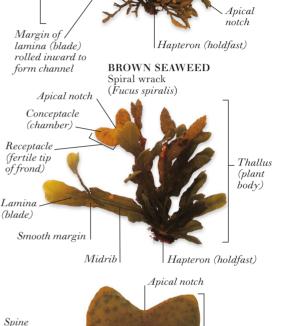
Coenobium

(colony of cells)

Volvox sp.

Thallus (plant body)

Thalassiosira sp.



BROWN SEAWEED

Receptacle (fertile tip

of frond)

Receptacle

(fertile tip

of frond)

Conceptacle

(chamber)

containing

reproductive

Channelled wrack (Pelvetia canaliculata)

Thallus

(plant

body)

Cytoplasm

acuole.

Plastid

organelle)

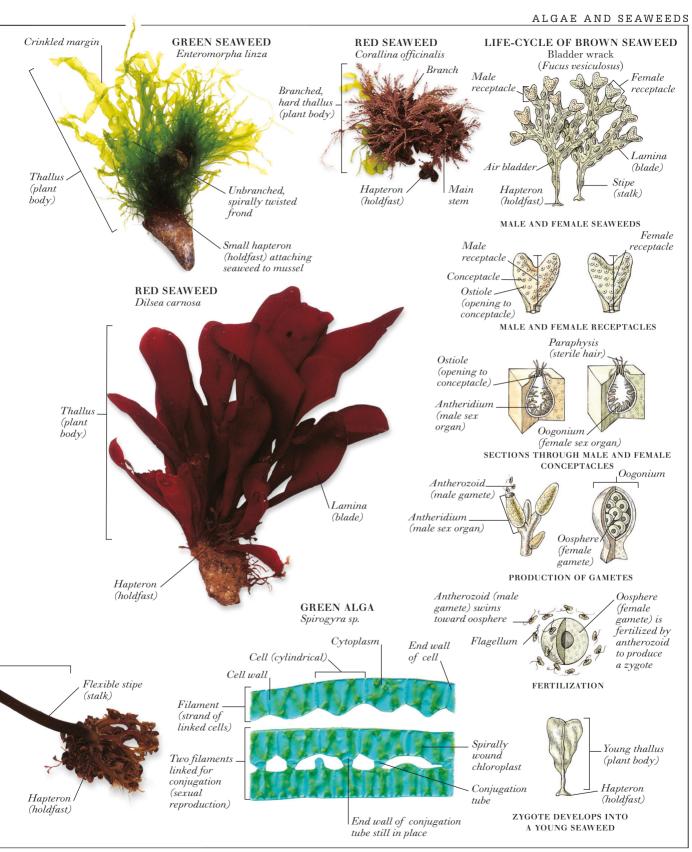
(photosynthetic

Lamina

structures) (blade) RECEPTACLE Spiral wrack (Fucus spiralis)

Midrib





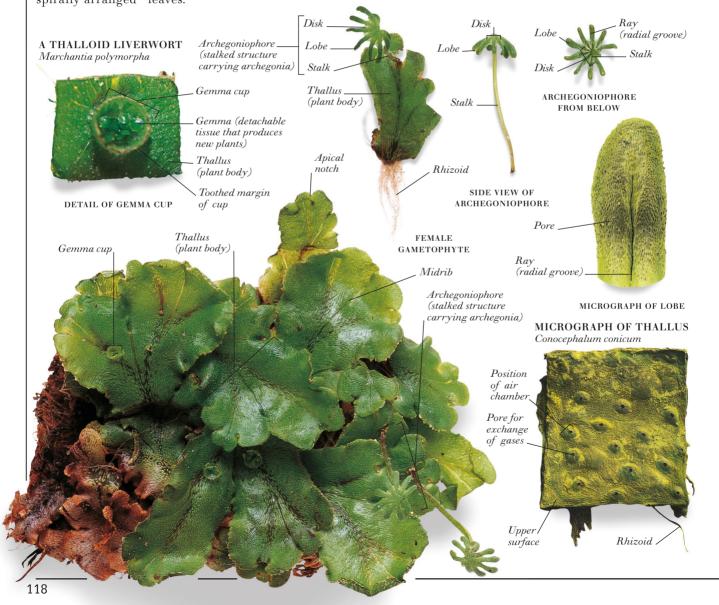
Liverworts and mosses

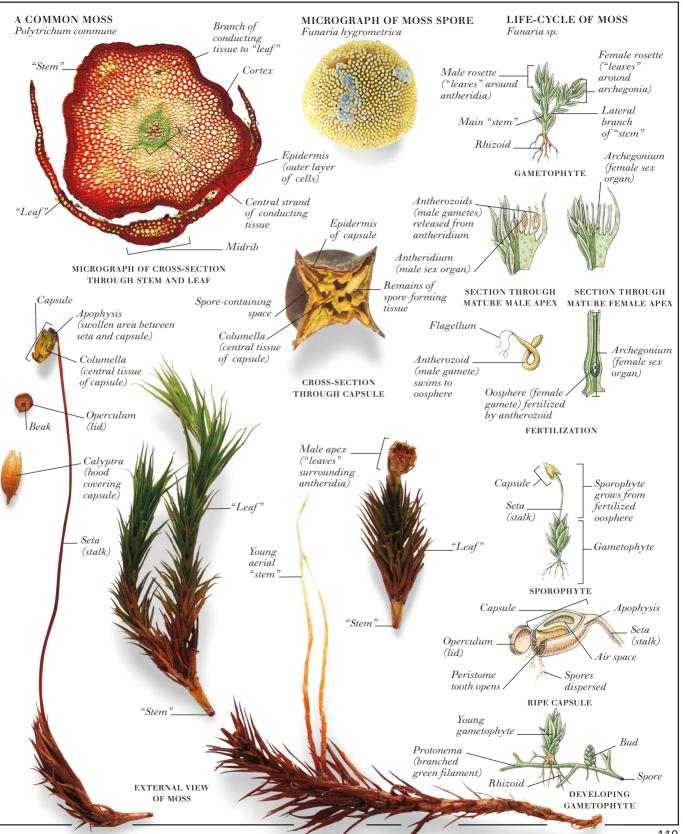
Liverworts and mosses are small, low-growing plants that belong to the phylum Bryophyta. Bryophytes do not have true stems, leaves, or roots (they are anchored to the ground by rhizoids), nor do they have the vascular tissues (xylem and phloem) that transport water and nutrients in higher plants. With no outer, waterproof cuticle, bryophytes are susceptible to drying out, and most grow in moist habitats. The bryophyte life-cycle has two stages. In stage one, the green plant (gametophyte) produces male and female gametes (sex cells), which fuse to form a zygote. In stage two, the zygote develops into a sporophyte that remains attached to the gametophyte. The sporophyte produces spores, which are released and germinate into new green plants. Liverworts (class Hepaticae) grow horizontally and may be thalloid (flat and ribbonlike) or "leafy." Mosses (class Musci) typically have an upright "stem" with spirally arranged "leaves."

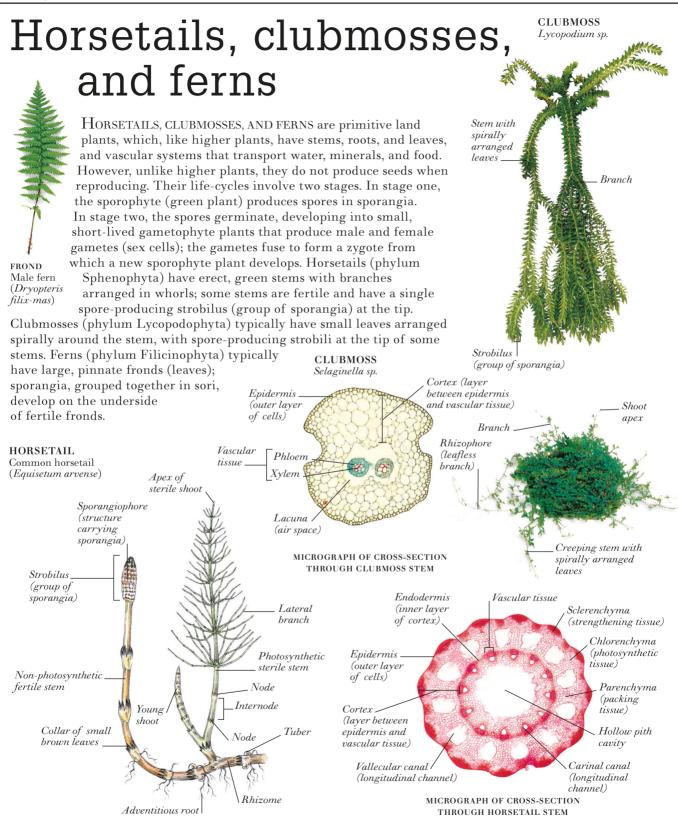
A LEAFY LIVERWORT

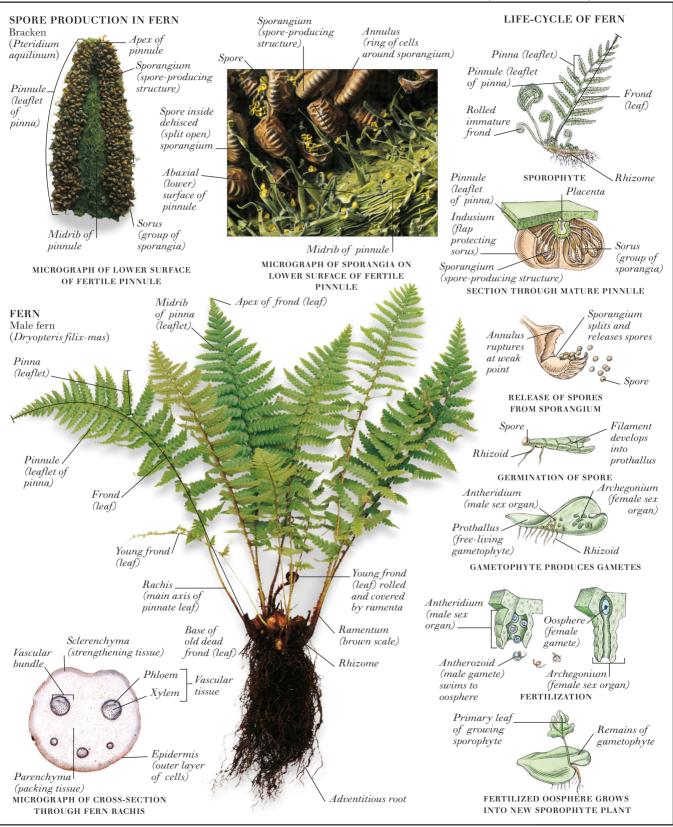
Scapania undulata









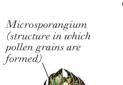


Gymnosperms 1

THE GYMNOSPERMS ARE FOUR RELATED PHYLA of seed-producing plants; their seeds, however, lack the protective, outer covering that surrounds the seeds of flowering plants. Typically, gymnosperms are woody, perennial shrubs or trees, with stems, leaves, and roots, and a well-developed vascular (transportat) system. The reproductive structures in most gymnosperms are cones: male cones produce microspores in which male gametes (sex cells) develop; female cones produce megaspores in which female gametes develop. Microspores are blown by the wind to female cones, male and female gametes fuse during fertilization, and a seed develops. The four gymnosperm phyla are the conifers (phylum Coniferophyta), mostly tall trees; cycads (phylum Cycadophyta), small palmlike trees; the ginkgo or maidenhair tree

(phylum Ginkgophyta), a tall tree with bilobed leaves; and gnetophytes (phylum Gnetophyta), a diverse group of plants, mainly shrubs, but also including the

horizontally growing welwitschia.



Wing of seed. derived from ovuliferous scale Seed Point of attachment. to axis of cone

Ovuliferous scale

(ovule- then seed-

bearing structure)

OVULIFEROUS SCALE FROM THIRD-YEAR FEMALE CONE

Pine

(Pinus sp.)

SCALE AND SEEDS

Wing

scale

Rract scale

of cone

structure)

scar

Microsporophyll(modified leaf Ovule carrying microsporangia) (contains female gametes) Scale leaf Ovuliferous scale (ovule- then seed-

bearing structure)

MICROGRAPH OF LONGITUDINAL SECTION THROUGH YOUNG MALE CONE

MICROGRAPH OF LONGITUDINAL SECTION THROUGH SECOND-YEAR FEMALE CONE

LIFE-CYCLE OF SCOTS PINE (Pinus sylvestris)



MALE CONES YOUNG FEMALE CONE Pollen grain in micropyle **Ovuliferous** (entrance to ovule) scale Pollen grain Ovule (contains Nucleus female Air sac gamete) POLLINATION

Archegonium

(containing

female

gamete)

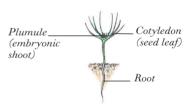
(outer part of ovule) Pollen tube (carries male gamete from

Integument

FERTILIZATION pollen grain

to ovum) Ovuliferous (ovule- then seed-bearing

MATURE FEMALE CONE AND WINGED SEED

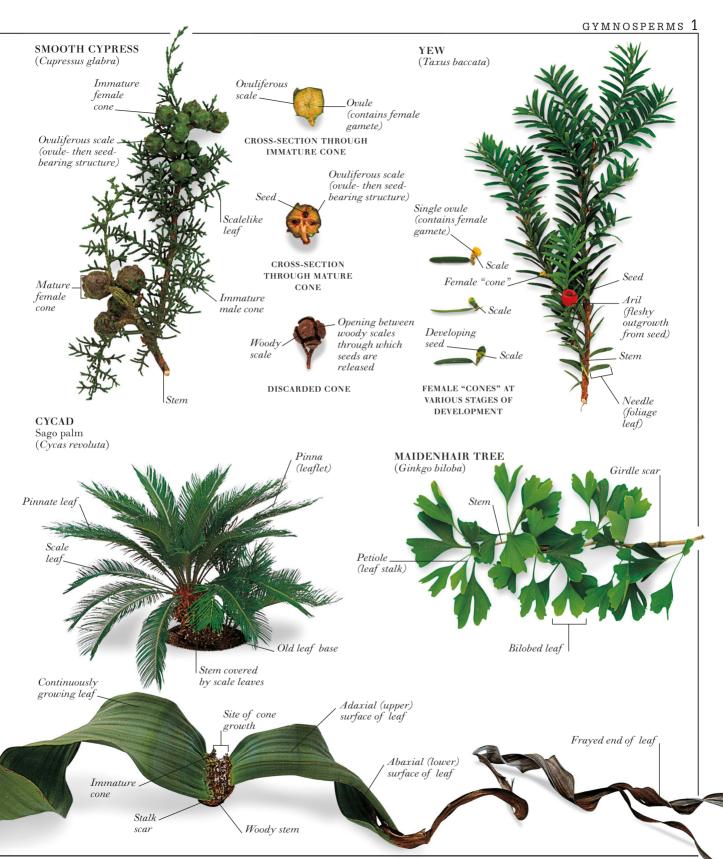


GERMINATION OF PINE SEEDLING

WELWITSCHIA (Welwitschia mirabilis)

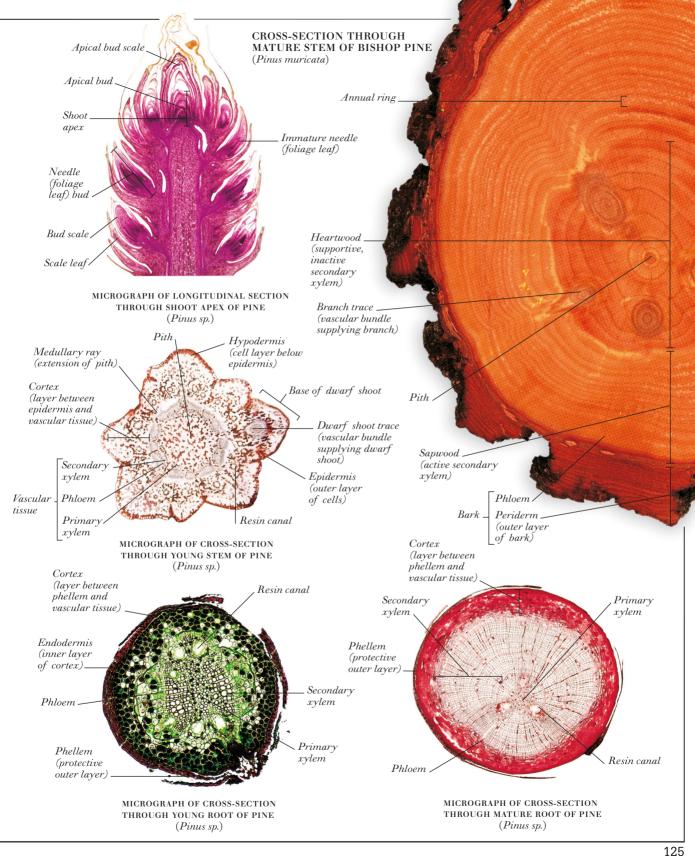


Axisof cone



Gymnosperms 2





Monocotyledons and dicotyledons

(parallel venation)

COMPARISONS BETWEEN

MONOCOTYLEDONS AND

Vein

Petiole _____ (leaf_stalk)

Emerging

leaf

Leaf base

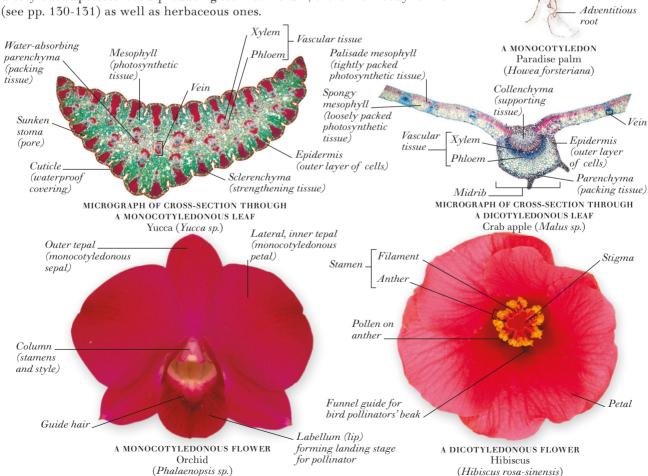
DICOTYLEDONS

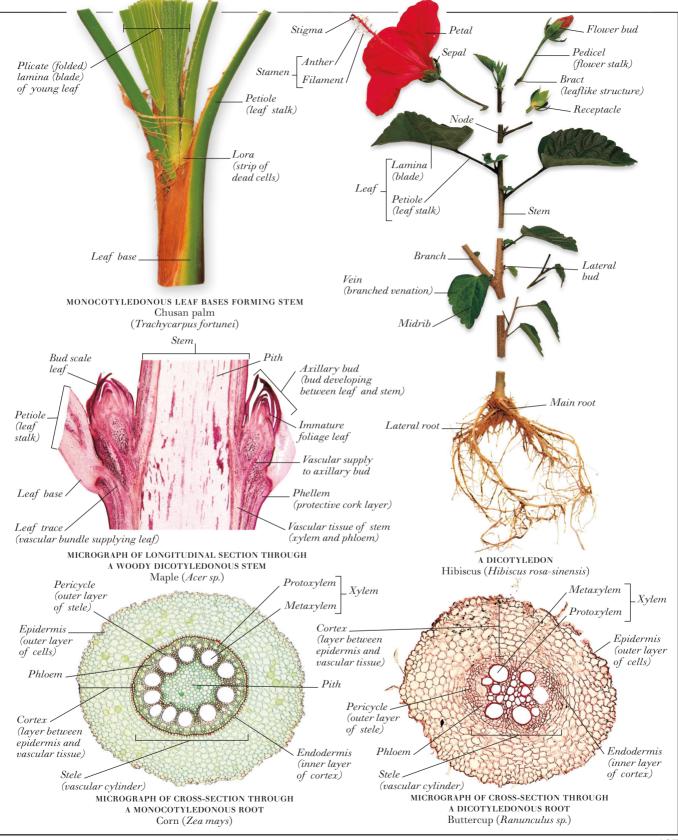
FLOWERING PLANTS (PHYLUM ANGIOSPERMOPHYTA) are divided into two classes:

monocotyledons (class Monocotyledoneae) and dicotyledons (class Dicotyledoneae). Typically, monocotyledons have seeds with one cotyledon (seed leaf); their foliage leaves are narrow with parallel veins; the flower components occur in multiples of three; sepals and petals are indistinguishable and are known

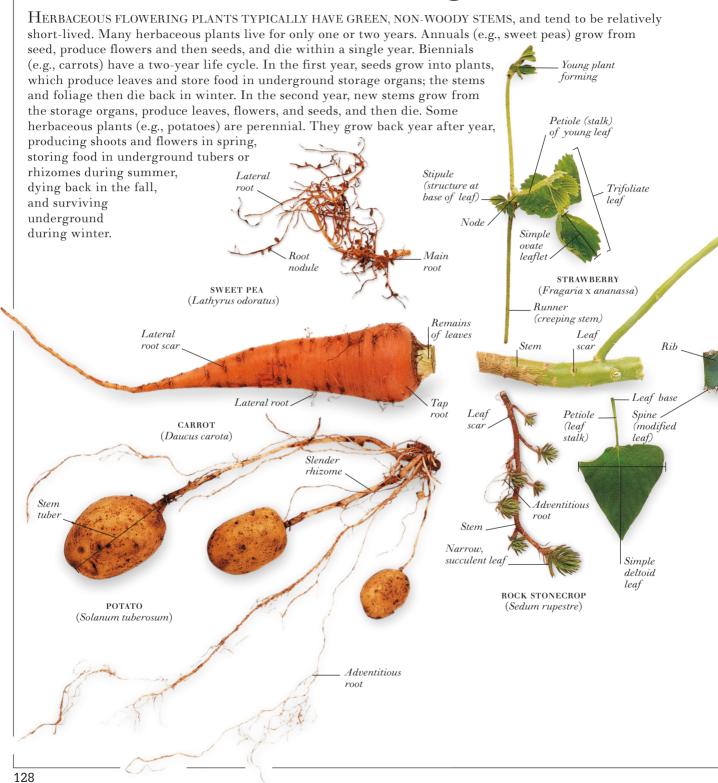
as tepals; vascular (transport) tissues are scattered in random bundles throughout the stem; and, since they lack stem cambium (actively dividing cells that produce wood), most monocotyledons are herbaceous (see pp. 128-129).

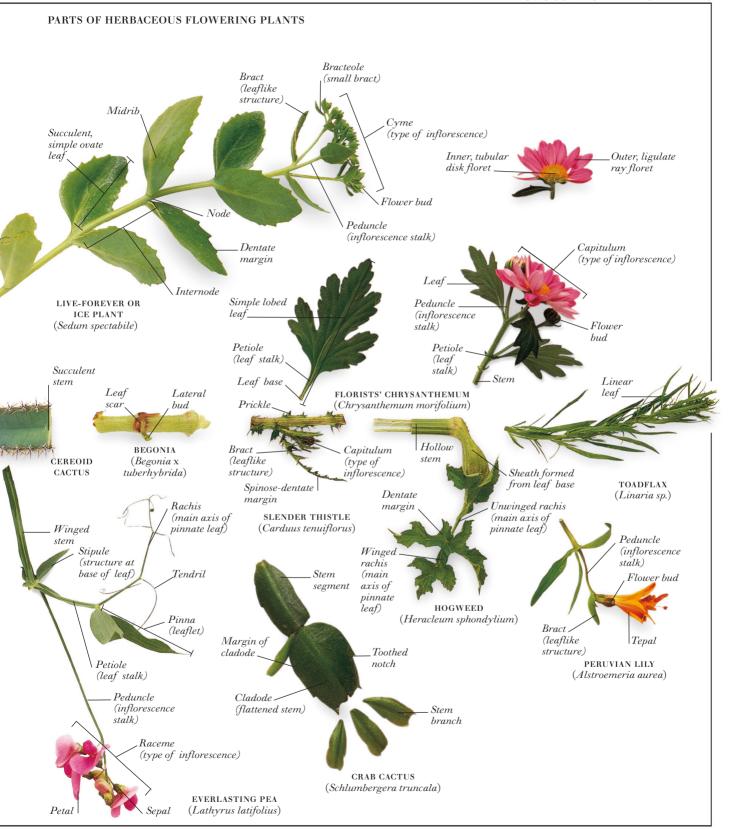
Dicotyledons have seeds with two cotyledons; leaves are broad with a central midrib and branched veins; flower parts occur in multiples of four or five; sepals are generally small and green; petals are large and colorful; vascular bundles are arranged in a ring around the edge of the stem; and, because many dicotyledons possess wood-producing stem cambium, there are woody forms (see pp. 130-131) as well as herbaceous ones.





Herbaceous flowering plants

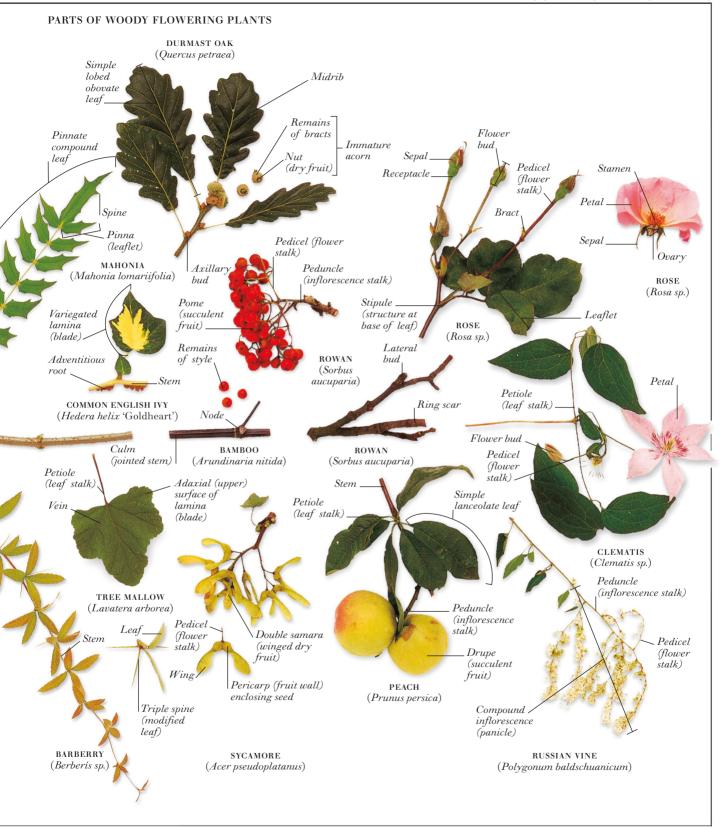




Woody flowering plants

WOODY FLOWERING PLANTS ARE PERENNIAL, that is, they continue to grow and reproduce for many years. They have one or more permanent stems above ground, and numerous smaller branches. The stems and branches have a strong woody core that supports the plant and contains vascular tissue for transporting water and nutrients. Outside the woody core is a layer of tough, protective bark, which has lenticels (tiny pores) in it to enable gases to pass through. Woody flowering plants may be shrubs, which have several stems arising from the soil; bushes, which are shrubs with dense branching and foliage; or trees, which typically have a single upright





CARROT

(Daucus carota)

Pericycle

of stele)

Root hair

(outer layer

Roots

Roots are the underground parts of plants. They have three main functions. First, they anchor the plant in the soil.

Second, they absorb water and minerals from the spaces between soil particles; the roots' absorptive properties are increased by root hairs, which grow behind the root tip, allowing maximum uptake of vital substances. Third, the root is part of the plant's transport system: xylem carries water and minerals from the roots to the stem and leaves, and phloem carries nutrients from the leaves to all parts of the root system. In addition, some roots (e.g., carrots) are food

FEATURES OF A TYPICAL ROOT

Buttercup

(Ranunculus sp.)

stores. Roots have an outer epidermis covering a cortex of parenchyma (packing tissue), and a central cylinder of vascular tissue. This arrangement helps the roots resist the forces of compression as they grow through the soil.

as seed (seed leaf) germinates Root hair Testa (seed.coat) Root tip Phloem sieve tube (region of (through which cell division) nutrients are (vascular cylinder) transported) Companion cell (cell associated with phloem sieve tube) Cortex (layer between epidermis and vascular tissue) Root hair

Cell wall

Nucleus

Cytoplasm

Parenchyma

(packing) cell

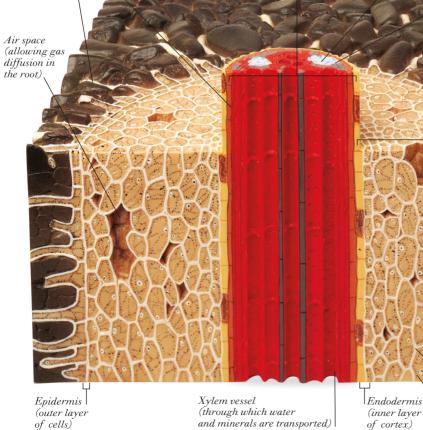
MICROGRAPH OF PRIMARY ROOT DEVELOPMENT

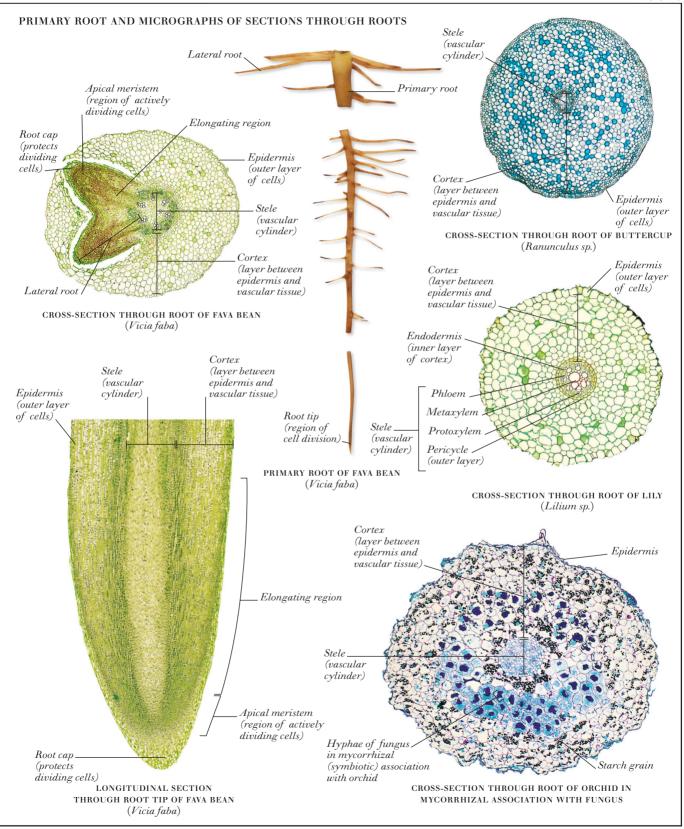
Cotyledon

Primary root

Cabbage (Brassica sp.)

Split in testa



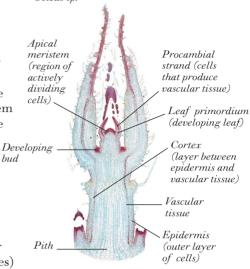


134

Stems

The stem is the main supportive part of a plant that grows above ground. Stems bear leaves (organs of photosynthesis), which grow at nodes; buds (shoots covered by protective scales), which grow at the stem tip (apical or terminal buds) and in the angle between a leaf and the stem (axillary or lateral buds); and flowers (reproductive structures). The stem forms part of the plant's transport system: xylem tissue in the stem transports water and minerals from the roots to the aerial parts of the plant, and phloem tissue transports nutrients manufactured in the leaves to other parts of the plant. Stem tissues are also used for storing water and food. Herbaceous (non-woody) stems have an outer protective epidermis covering a cortex that consists mainly of parenchyma (packing tissue) but also has some collenchyma (supporting tissue). The vascular tissue of such stems is arranged in bundles, each of which consists of xylem, phloem, and sclerenchyma (strengthening tissue). Woody stems have an outer protective layer of tough bark, which is perforated with lenticels (pores) to allow gas exchange. Inside the bark is a ring of secondary phloem, which surrounds an inner core of secondary xylem.

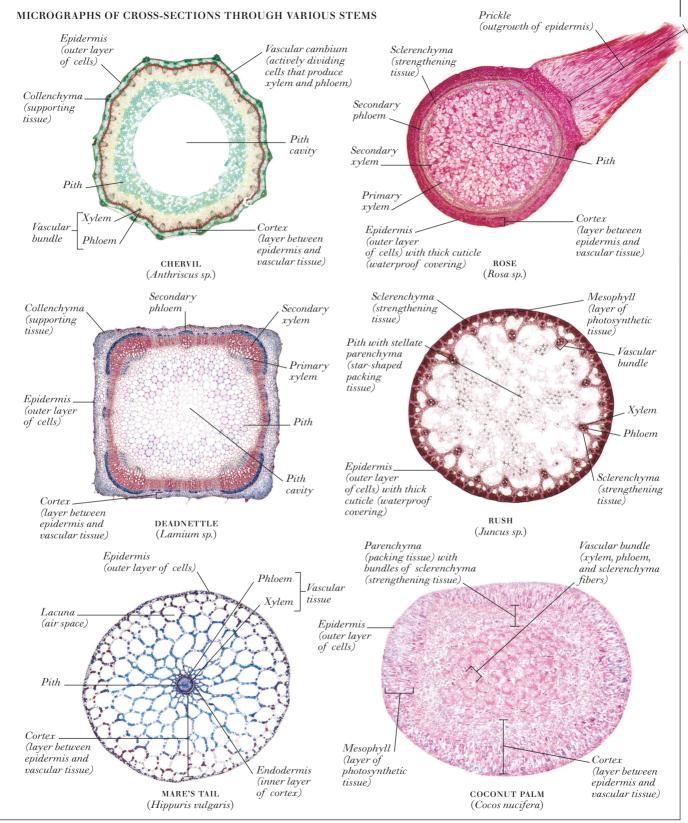
MICROGRAPH OF LONGITUDINAL SECTION THROUGH APEX OF STEM Coleus sp.



Young

leaves emerging

YOUNG WOODY STEM EMERGENT BUDS London plane Lime (Platanus x acerifolia) (Tilia sp.) PhellemPith Secondary (protective Terminal bud. phloem cork layer) Corter (layer between phellem and vascular tissue, Xylem vessel Lateral bud (through which water and minerals are transported) Vascular cambium (actively dividing cells Xylem fiber that produce xylem Internode (supporting and phloem) tissue) Inner Ray_ Fall bud scale (parenchyma wood . Secondary cells) xylem Spring wood Phloem sieve tube Outer (through which bud scale nutrients are Leaf scar transported) Node Companion cell (cell associated Phloem fiber with phloem (supporting sieve tube) Lenticel tissue) (pore) Woody Lenticel . stem (pore)



FEATURES

Lamina (blade)

Leaves

SIMPLE LEAF SHAPES

Leaves are the main sites of photosynthesis (see pp. 138-139) and transpiration (water loss by evaporation) in plants. A typical leaf consists of a thin, flat lamina (blade) supported by a network of veins; a petiole (leaf stalk); and a leaf base, where the petiole joins the stem. Leaves can be classified as simple, in which

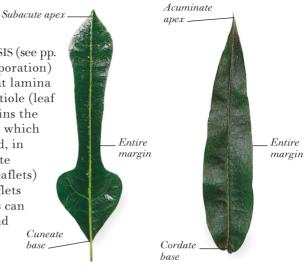
CHECKERBLOOM (Sidalcea malviflora) the lamina is a single unit, or compound, in which the lamina is divided into separate

leaflets. Compound leaves may be pinnate, with pinnae (leaflets) on both sides of a rachis (main axis), or palmate, with leaflets arising from a single point at the tip of the petiole. Leaves can be classified further by the overall shape of the lamina, and

be classified further by the overall shape of the lamina, and by the shape of the lamina's apex, margin, and base.

Apex

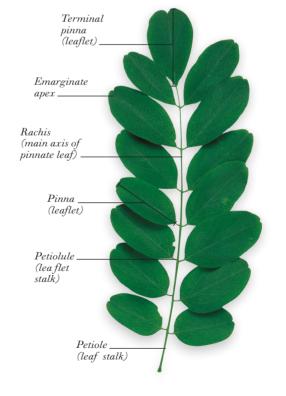
GENERAL LEAF

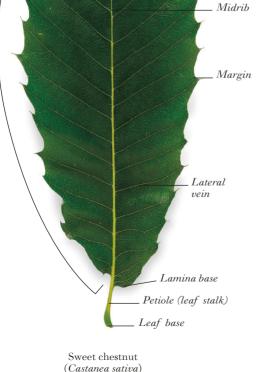


PANDURIFORM Croton (Codiaeum variegatum)

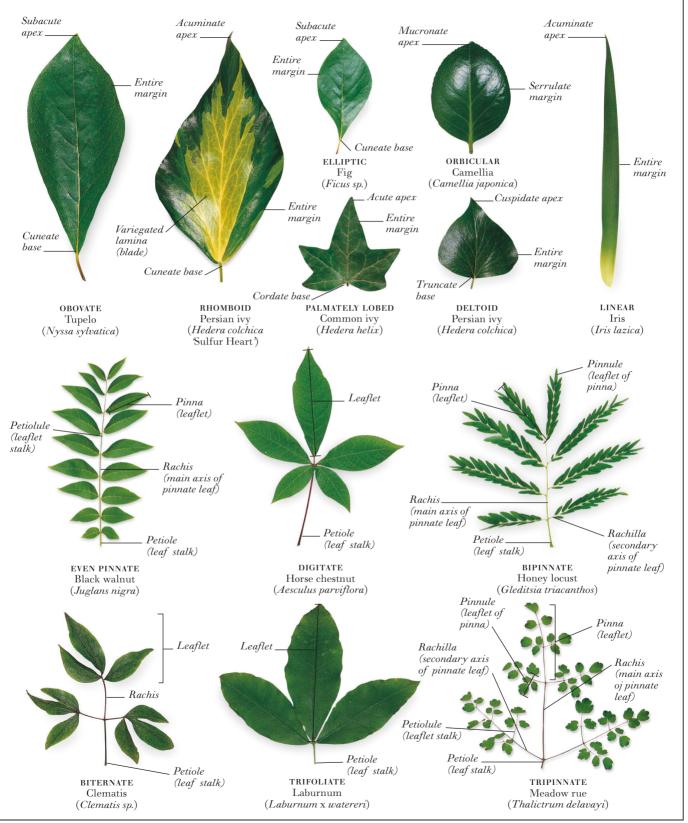
LANCEOLATE Sea buckthorn (*Hippophae rhamnoides*)

COMPOUND LEAF SHAPES





ODD PINNATE False acacia (Robinia pseudoacacia)

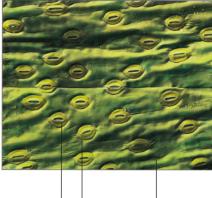


Photosynthesis

Photosynthesis is the process by which plants make their food using sunlight, water, and carbon dioxide. It takes place inside special structures in leaf cells called chloroplasts. The chloroplasts contain chlorophyll, a green pigment that absorbs energy from sunlight. During photosynthesis, the absorbed energy is used to join together carbon dioxide and water to form the sugar glucose, which is the energy source for the whole plant; oxygen, a waste product, is released into the air. Leaves are the main sites of photosynthesis, and have various adaptations for that purpose: flat laminae (blades) provide a large surface for absorbing sunlight; stomata (pores) in the lower surface of the laminae allow gases (carbon dioxide and oxygen) to pass into and out of the leaves; and an extensive network of veins brings water into the leaves and transports the glucose produced by photosynthesis to the rest of the plant.

MICROGRAPH OF LEAF

Lily (Lilium sp.)

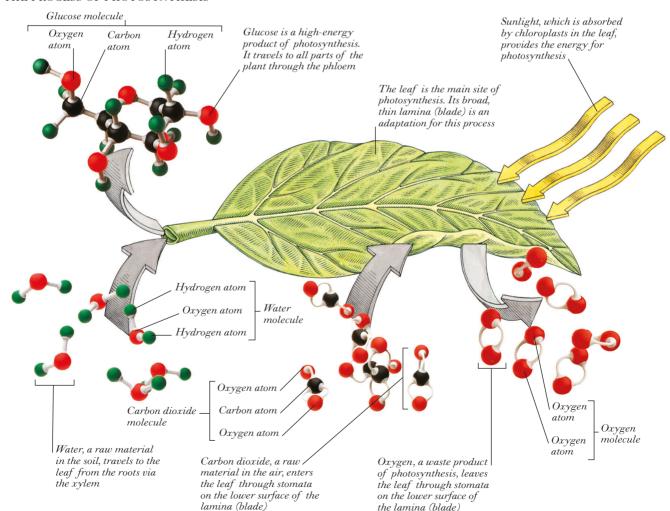


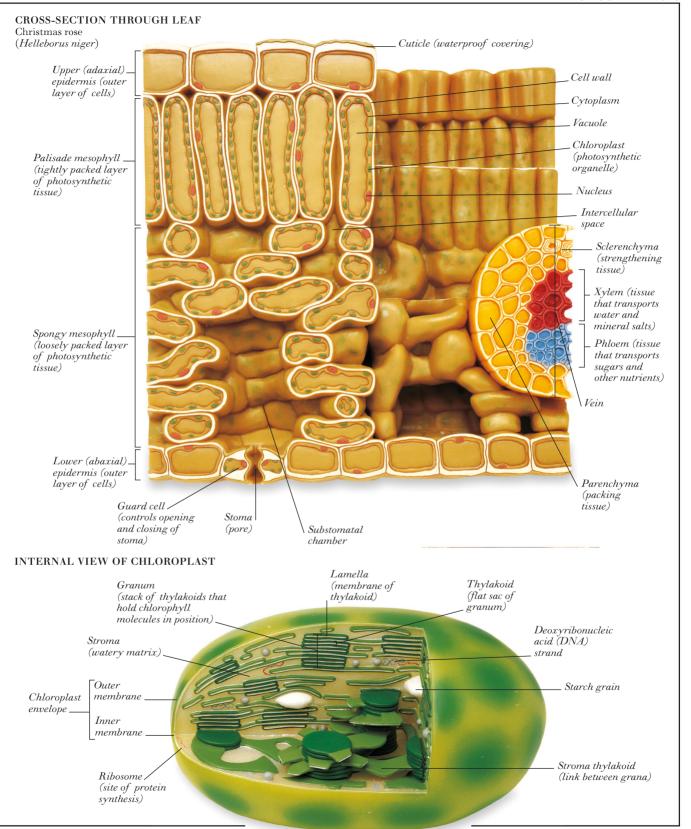
Stoma (pore)

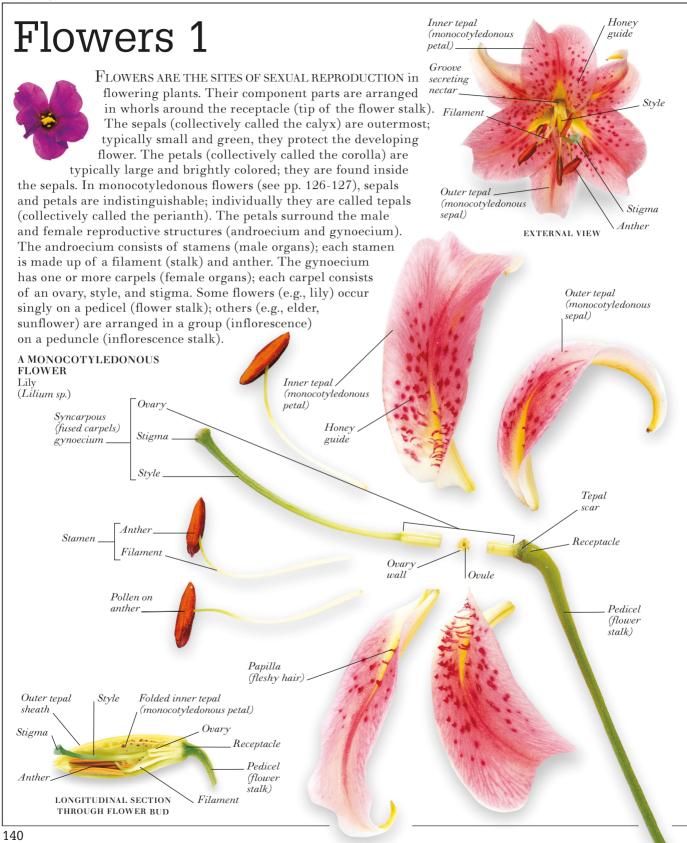
Guard cell (controls opening and closing of stoma)

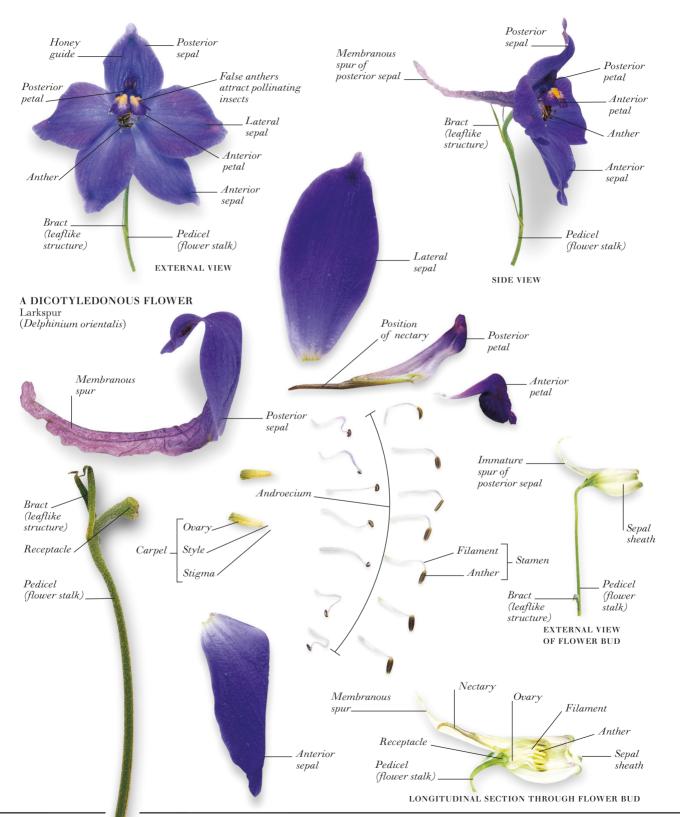
Lower surface of lamina (blade)

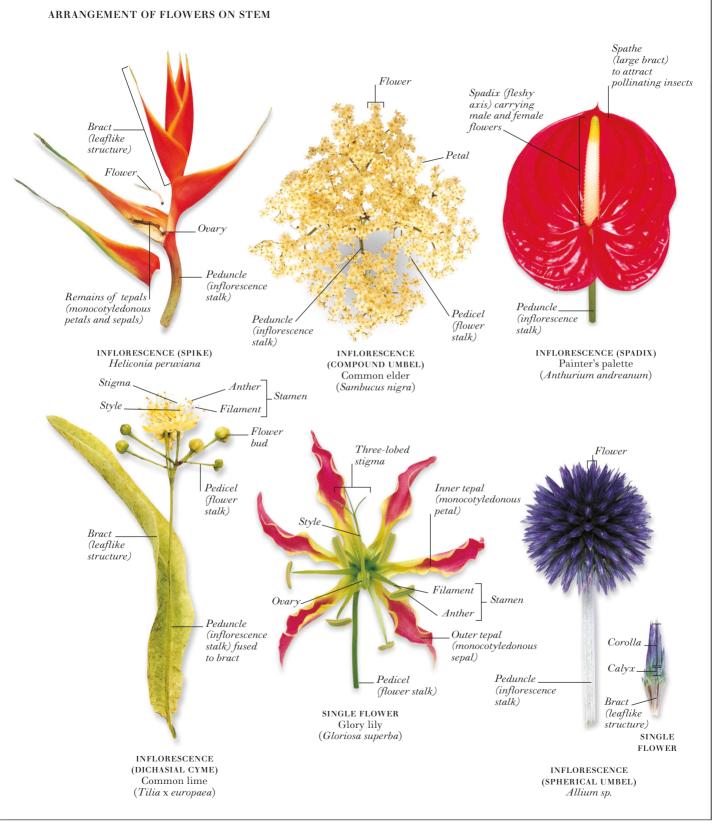
THE PROCESS OF PHOTOSYNTHESIS



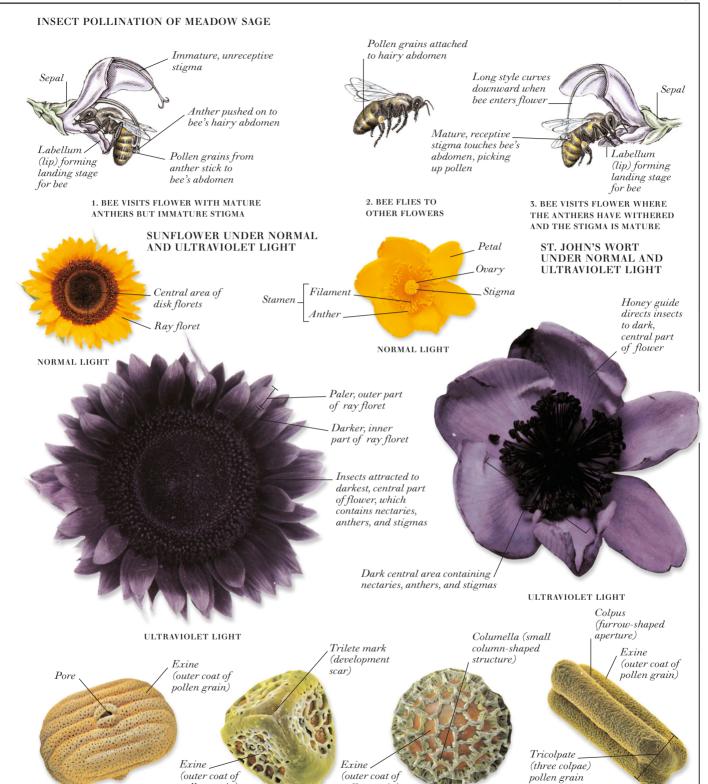








REPRODUCTIVE STRUCTURES IN Pollination WIND-POLLINATED PLANT Sweet chestnut (Castanea saliva) POLLINATION IS THE TRANSFER OF POLLEN (which contains the male sex cells) from an anther (part of the male Flower bud. Male reproductive organ) to a stigma (part of the female flower Prominent stigma protrudes from flower reproductive organ). This process precedes fertilization (see pp. 146-147). Pollination may occur within the same Female flower flower (self-pollination), or between flowers on separate Peduncle Part of male plants of the same species (cross-pollination). (inflorescence Petiole catkin In most plants, pollination is carried out either stalk) (leaf stalk) (inflorescence by insects (entomorphilous pollination) or by the adapted for wind (anemophilous pollination). Less commonly, Bract. wind Filament (leaflike pollination) birds, bats, or water are the agents of pollination. structure) Insect-pollinated flowers are typically brightly Anther Peduncle. colored, scented, and produce (inflorescence nectar, on which insects stalk) feed. Such flowers also Stigma MALE tend to have patterns that REPRODUCTIVE STRUCTURES IN are visible only in ultraviolet INSECT-POLLINATED PLANTS light, which many insects can see but which humans cannot. Endothecium . These features attract insects. (pollen sac wall) which become covered with the sticky or hooked pollen grains Pollenwhen they visit one flower, Dehisced grain (split open) and then transfer the pollen pollen sac Anther to the next flower they visit. Stamen Wind-pollinated flowers are Filament generally small, relatively inconspicuous, and unscented. Boundary between They produce large quantities two fused carpels (each carpel of light pollen grains that are consists of a stigma, easily blown by the wind to style, and ovary) other flowers. Calvx(whorl of Ovary sepals) MICROGRAPHS OF MICROGRAPH OF CARPELS (FEMALE ORGANS) MICROGRAPH OF STAMENS (MALE ORGANS) POLLEN GRAINS Yellow-wort Common centaury Exine (outer coat of pollen (Blackstonia perfoliata) (Centaurium erythraea) grain) Colpus Colpus (furrow-shaped Exine (furrow-shaped aperture) (outer aperture) coat of pollen Exine (outer grain) coat of pollen grain) Baculum Exine (rod-shaped **Equatorial** (outer coat of pollen grain) structure) furrow JUSTICIA AUREA MEADOW CRANESBILL EUROPEAN FIELD ELM BOX-LEAVED MILKWORT (Polygala chamaebuxus) (Ulmus minor) (Geranium pratense)



pollen grain)

RUELLIA GRANDIFLORA

THESIUM ALPINIUM

pollen grain)

MIMULOPSIS SOLMSII

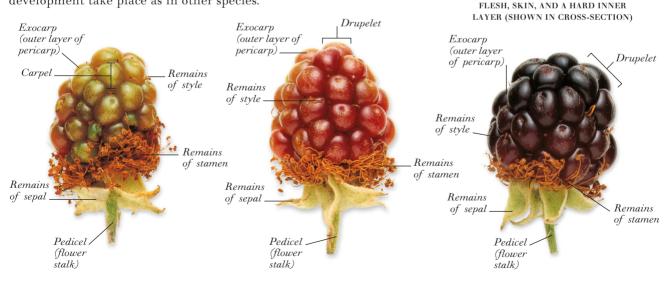
CROSSANDRA NILOTICA

Fertilization

FERTILIZATION IS THE FUSION of male and female gametes (sex cells) to produce a zygote (embryo). Following pollination (see pp. 144-145), the pollen

grains that contain the male gametes are on Stamen the stigma, some distance from the female gamete (ovum) inside the ovule. To enable the gametes to meet, the pollen grain germinates and produces a pollen tube, which grows down and enters the embryo sac (the inner part of the ovule that contains the ovum). Two male gametes, traveling at the tip of the pollen tube, enter the embryo sac. One gamete fuses with the ovum to produce a zygote that will develop into an embryo plant. The other male gamete fuses with two polar nuclei to produce the endosperm, which acts as a food supply for the developing embryo. Fertilization also initiates other changes: the integument (outer part of ovule) forms a testa (seed coat) around the embryo and endosperm; the petals fall off; the stigma and style wither; and the ovary wall forms a layer (called the pericarp) around the seed. Together, the pericarp and seed form the fruit, which may be succulent (see pp. 148-149) or dry (see pp. 150-151). In some species (e.g., blackberry), apomixis can

BANANA In some species (e.g., blackberry), apomixis can (Musa 'lacatan') occur: the seed develops without fertilization of the ovum by a male gamete but endosperm formation and fruit development take place as in other species.



7. MESOCARP (FLESHY PART OF PERICARP) OF EACH CARPEL STARTS TO CHANGE COLOR 8. CARPELS MATURE INTO DRUPELETS (SMALL FLESHY FRUITS WITH SINGLE SEEDS SURROUNDED BY HARD ENDOCARP) 9. MESOCARP OF DRUPELET BECOMES DARKER AND SWEETER

DEVELOPMENT OF A SUCCULENT FRUIT

1. FLOWER IN FULL BLOOM

ATTRACTS POLLINATORS

Remains of

Receptacle

Remains

Pedicel

(flower

stalk)

of stamen

style

Carpel

Abortive

4. PERICARP FORMS

seed

Blackberry (Rubus fruticosus)

Petal

Filament

Anther

Ovary

Stigma

Style

Endocarp

Mesocarp

(middle

layer of

pericarp)

Exocarp

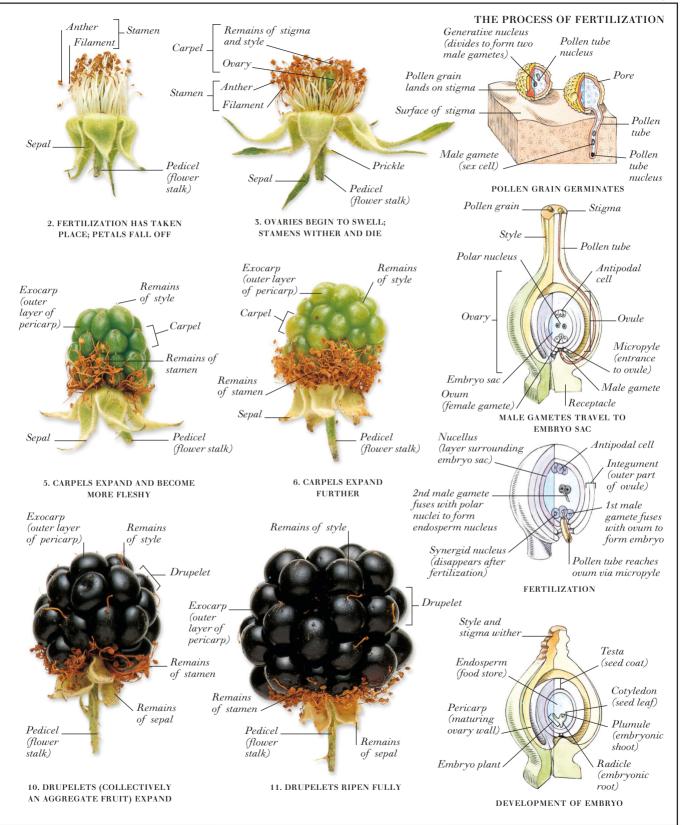
layer of

pericarp)

Sepal

(outer

(inner layer of pericarp)



Succulent fruits

A FRUIT IS A FULLY DEVELOPED and ripened ovary (seed-producing part of a plant's female reproductive organs). Fruits may be succulent or dry

(see pp. 150-151). Succulent fruits are fleshy and brightly colored, making them attractive to animals, which eat them and so disperse the seeds away from the parent plant. The wall (pericarp) of a succulent fruit has three layers: an outer exocarp, a middle mesocarp, and an inner endocarp. These three layers vary in thickness and texture in different types of fruits and may blend into each other. Succulent fruits can be classed as simple (derived from one ovary) or compound (derived

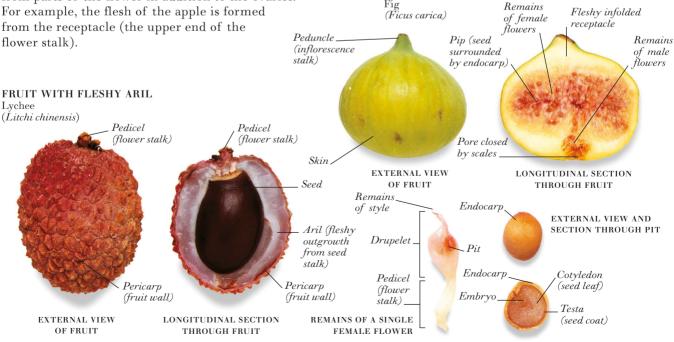
BERRY one ovary) or compound (derived Cocoa from several ovaries). Simple succulent fruits include berries,

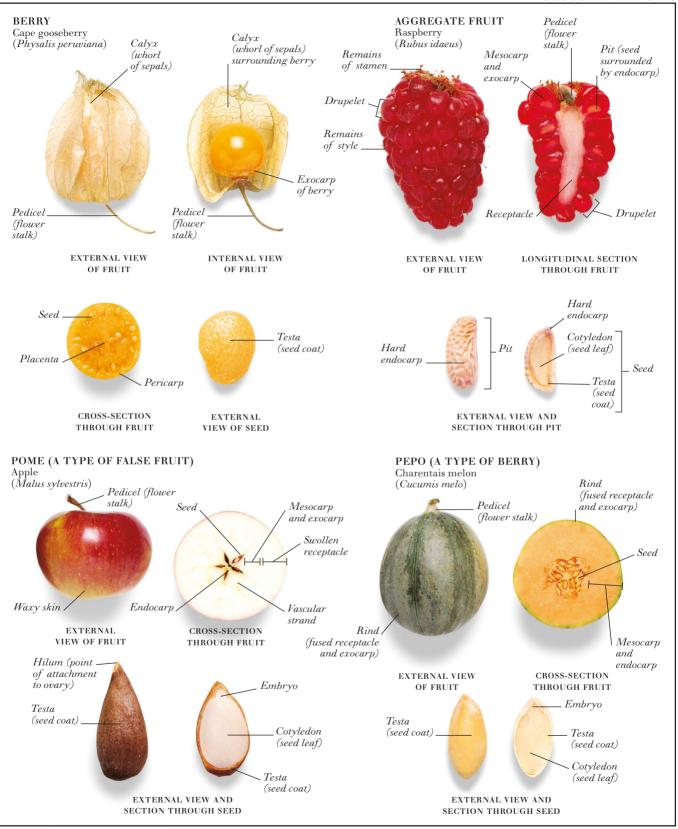
which typically have many seeds, and drupes, which typically have a single stone or pit (e.g., cherry and peach). Compound succulent fruits include aggregate fruits, which are formed from many ovaries in one flower, and multiple fruits, which develop from the ovaries of many flowers. Some fruits, known as false fruits or pseudocarps, develop from parts of the flower in addition to the ovaries. For example, the flesh of the apple is formed from the receptacle (the upper end of the flower stalk).

HESPERIDIUM (A TYPE OF BERRY) (Citrus limon) Pedicel (flower stalk) Endocarp Pedicel Exocarp Mesocary (flower stalk) Seed Leathery exocarp Vesicle Oil (juice gland sac) Remains Placenta Remains of style of style. EXTERNAL VIEW LONGITUDINAL SECTION THROUGH FRUIT OF FRUIT EmbryoSeed

Hilum Carpel (point of wall attachment to ovary) Carpel Testa (seed Placenta Cotyledon coat) (seed leaf) EXTERNAL VIEW AND CROSS-SECTION SECTION THROUGH SEED THROUGH FRUIT

SYCONIUM (A TYPE OF FALSE FRUIT)





NUTLET

Goosegrass (Galium aparine)

Dry fruits

Dry fruits have a hard, dry pericarp (fruit wall)

around their seeds unlike succulent fruits, which have fleshy of sepal pericarps (see pp. 148-149). Dry fruits are divided into three types:

dehiscent, in which the pericarp splits open to release the seeds; indehiscent, which do not split open; and schizocarpic, in which the fruit splits but the seeds are not exposed. Dehiscent dry fruits include capsules (e.g., love-in-a-mist), follicles (e.g., delphinium), legumes (e.g., pea), and siliquas (e.g., honesty). Typically, the seeds of dehiscent fruits are dispersed by the wind. Indehiscent dry fruits include nuts (e.g., sweet chestnut), nutlets (e.g., goosegrass), achenes (e.g., strawberry), caryopses

LEGUME

(Pisum sativum)

Receptacle

Pedicel

Receptacle

Remains

of stamen

Placenta

Pericarp

(fruit

wall)

Remains of

SECTION THROUGH SEED

style and

stigma

EXTERNAL VIEW

OF FRUIT

(flower stalk)

Pedicel.

(flower

Remains

of sepal

Funicle

attaching

Pericarp

(fruit

wall)

Seed

Remains of

style and

stigma

INTERNAL VIEW

OF FRUIT

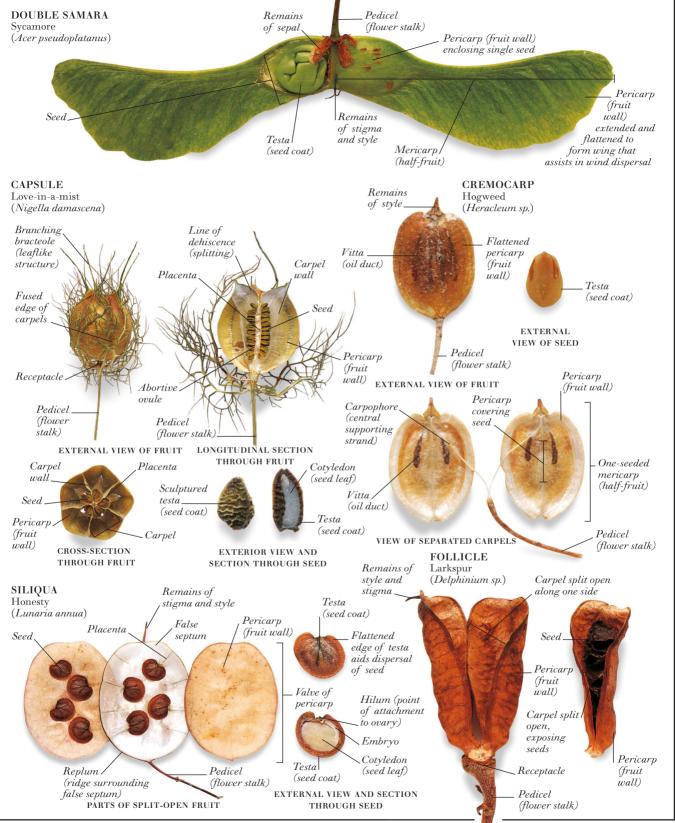
(stalk

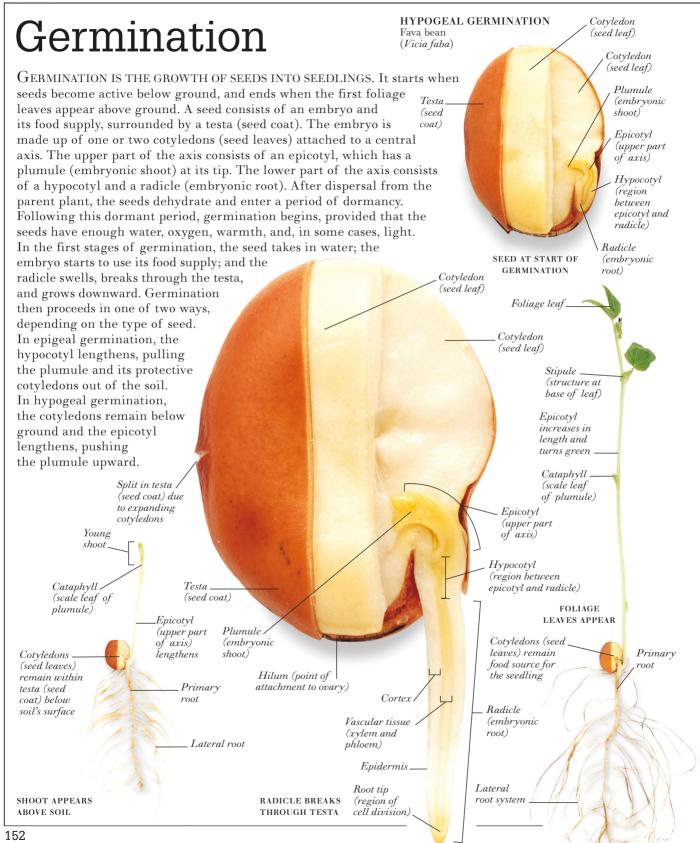
seed to placenta)

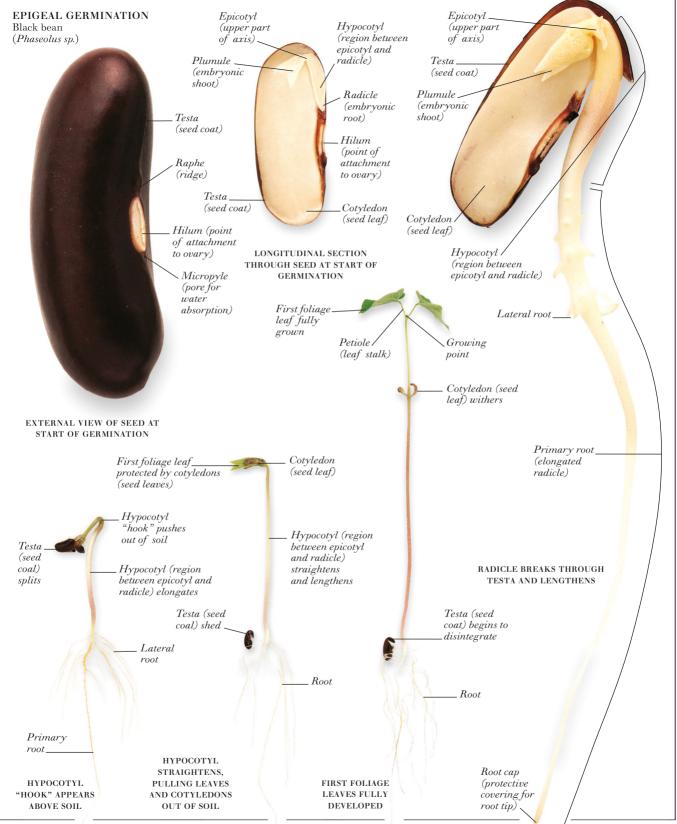
(e.g., wheat), samaras (e.g., elm), and cypselas (e.g., dandelion). Some indehiscent dry fruits are dispersed by the wind, assisted by "wings" (e.g., elm) or "parachutes" (e.g., dandelion); others (e.g., goosegrass) have hooked pericarps to aid dispersal on animals' fur. Schizocarpic dry fruits include cremocarps (e.g., hogweed), and double samaras (e.g., sycamore Funicle

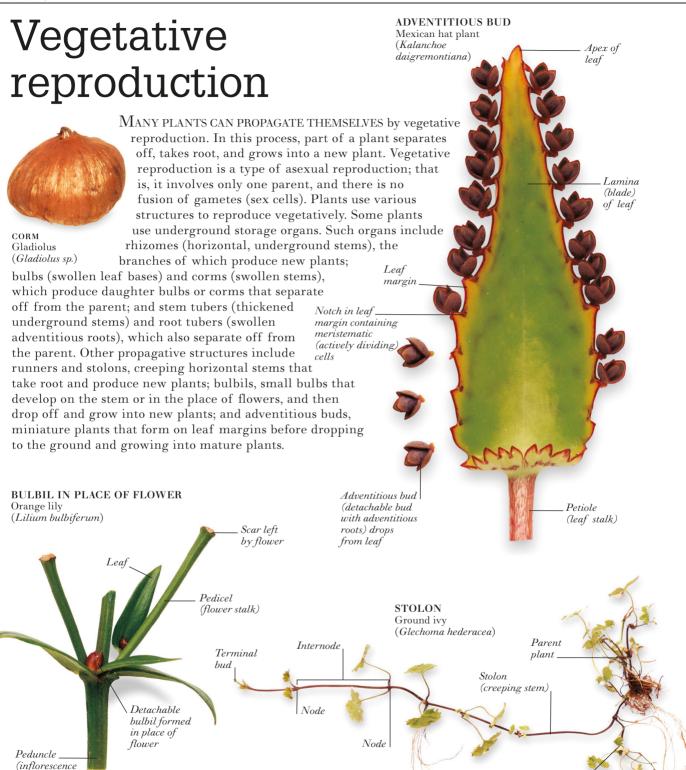
SECTION THROUGH FRUIT

maple); these are dispersed by the wind. (stalk attaching seed to placenta) Cotyledon NUT Line of splitting (seed leaf) Radicle Sweet chestnut (embryonic between valves (Castanea sativa) root) of cupule Micropyle. (pore for water Testa Peduncle (seed Plumule absorption) coat) (embryonic (inflorescence stalk) Testa shoot) (seed coat) EXTERIOR VIEW AND Remains SECTION THROUGH SEED of male inflorescence ACHENE Strawberry Pedicel Nut(Fragaria x ananassa) (flower (indehiscent Pedicel Sepal (flower stalk) stalk) Sepal fruit) Spiked cupule husk around Swollen fruit formed receptacle from bracts) EXTERNAL VIEW OF FRUIT WITH SURROUNDING CUPULE Remains of stigma Remains and style Swollen Remains of stigma. Remains fleshy tissues of stigma of style of receptacle Achene Remains (one-seeded of style LONGITUDINAL SECTION *dry fruit)* EXTERNAL VIEW THROUGH FRUIT OF FRUIT Pericarp Embryo(fruit Cotyledon (indehiscent wall) Cotyledon (seed leaf) Pericarp fruit) (seed leaf) (fruit wall) Testa Testa (seed coat) (seed coat) Woody pericarp Woody pericarp (fruit wall) EXTERNAL VIEW AND (fruit wall) EXTERNAL VIEW AND









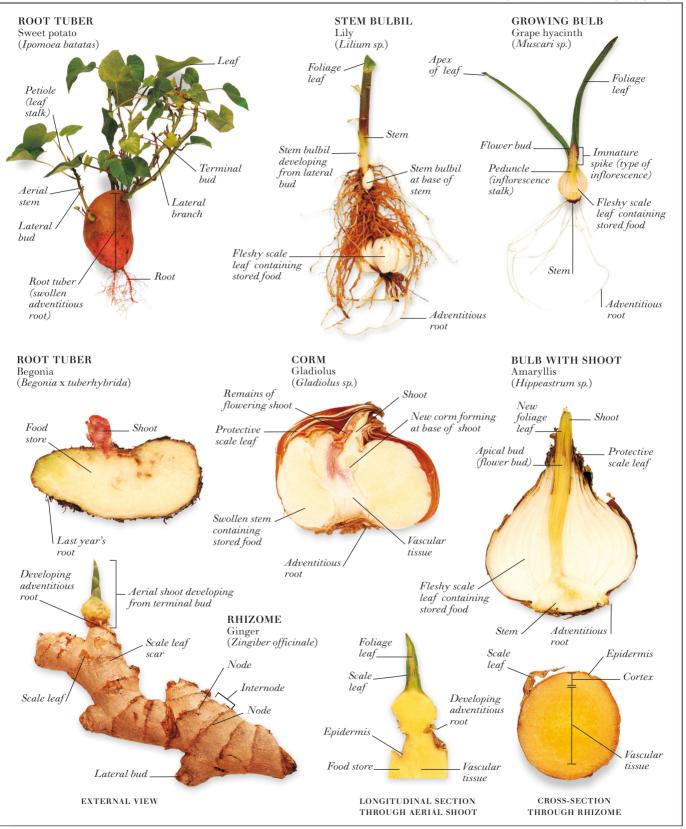
Adventitious root

of daughter plant

Daughter plant

developed from lateral bud

stalk)



Dryland plants

STEM SUCCULENT Golden barrel cactus (Echinocactus grusonii)



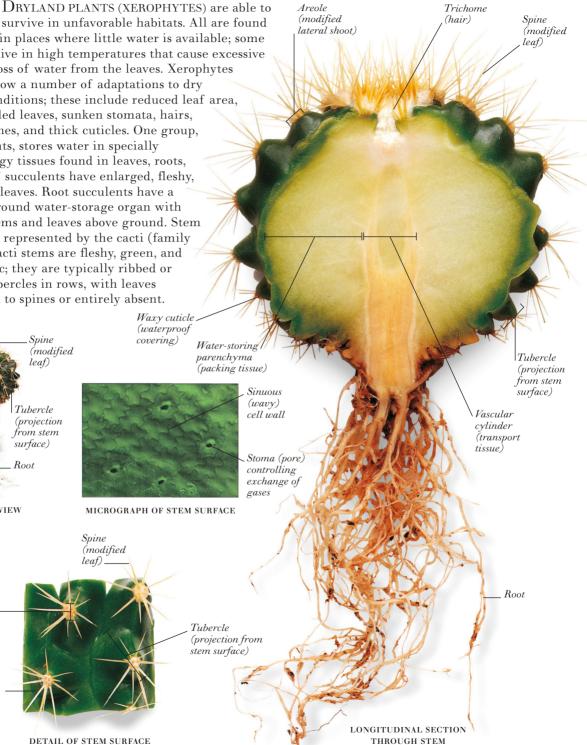
LEAF

Lithops sp.

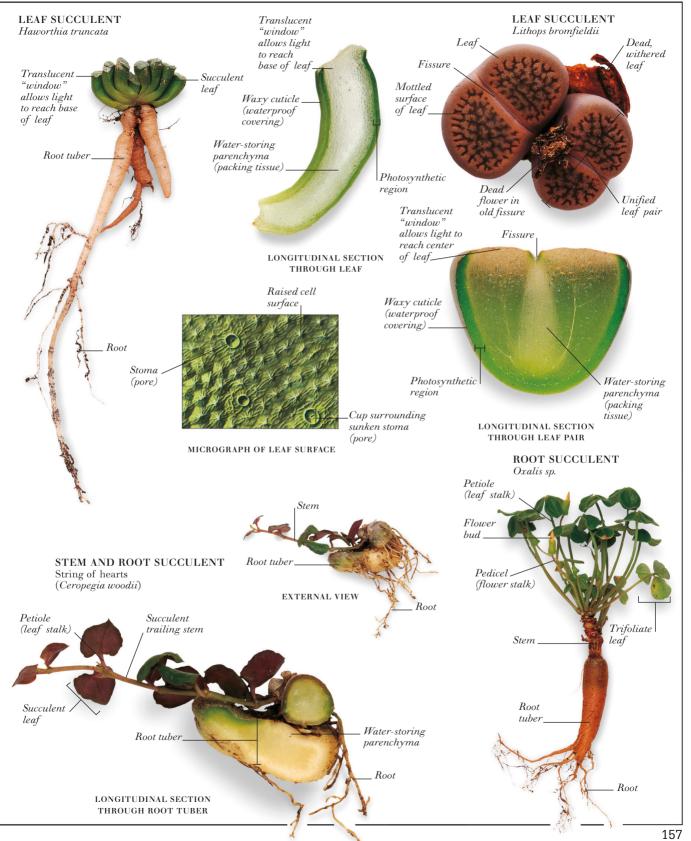
in places where little water is available; some live in high temperatures that cause excessive loss of water from the leaves. Xerophytes show a number of adaptations to dry conditions; these include reduced leaf area, SUCCULENT rolled leaves, sunken stomata, hairs, spines, and thick cuticles. One group, succulent plants, stores water in specially enlarged spongy tissues found in leaves, roots, or stems. Leaf succulents have enlarged, fleshy, water-storing leaves. Root succulents have a large, underground water-storage organ with short-lived stems and leaves above ground. Stem succulents are represented by the cacti (family Cactaceae). Cacti stems are fleshy, green, and photosynthetic; they are typically ribbed or covered by tubercles in rows, with leaves being reduced to spines or entirely absent.



DETAIL OF STEM SURFACE

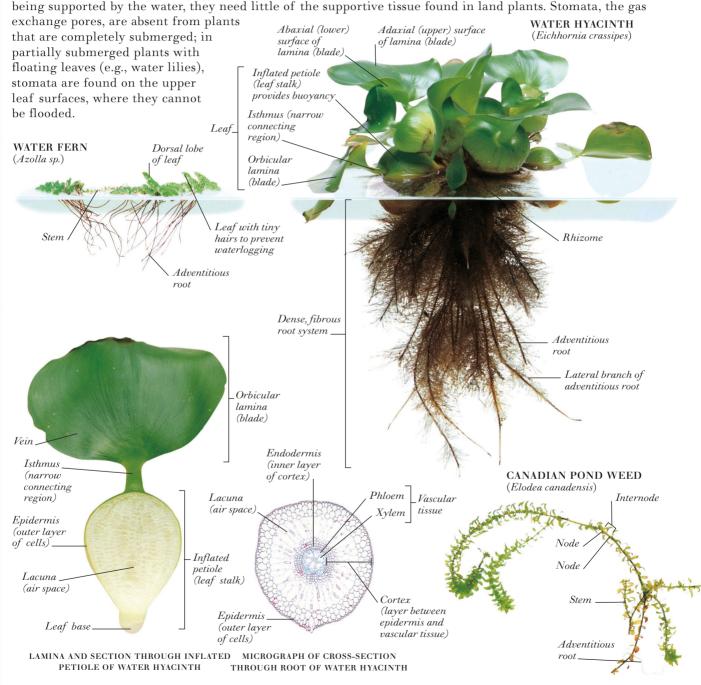


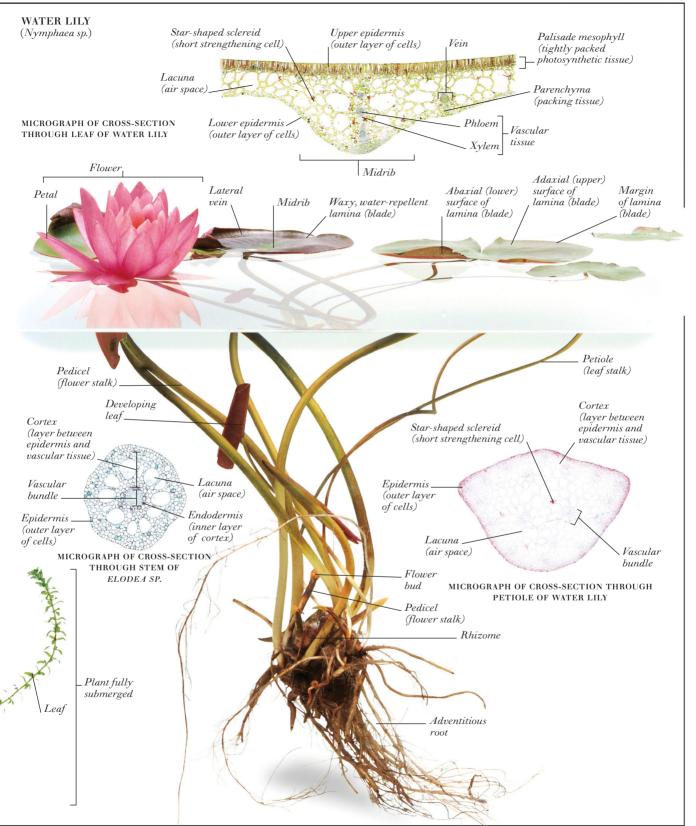
Waxy cuticle (waterproof covering)

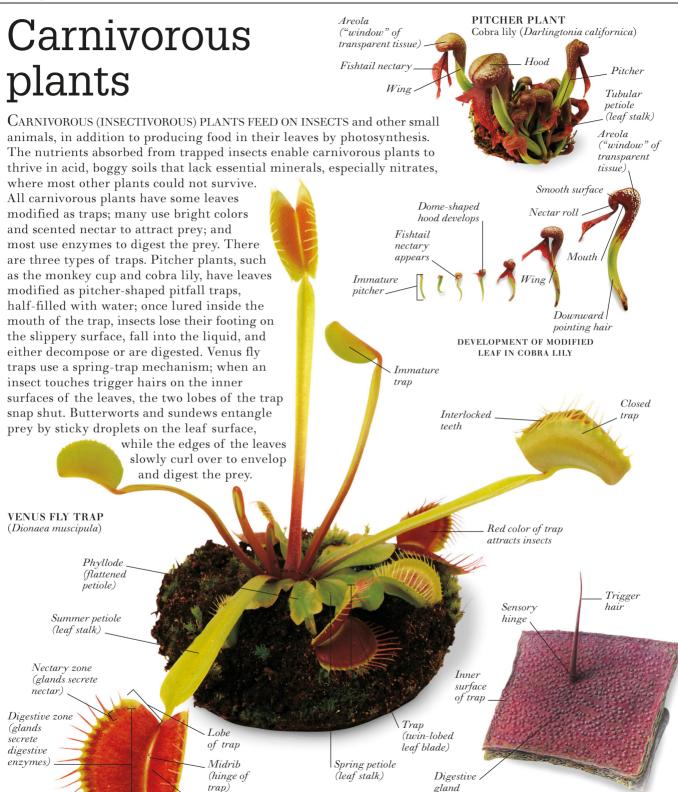


Wetland plants

WETLAND PLANTS GROW SUBMERGED IN WATER, either partially (e.g., water hyacinth) or completely (e.g., pond weeds), and show various adaptations to this habitat. Typically, there are numerous air spaces inside the stems, leaves, and roots; these aid gas exchange and buoyancy. Submerged parts generally have no cuticle (waterproof covering), enabling the plants to absorb minerals and gases directly from the water; in addition, being supported by the water, they need little of the supportive tissue found in land plants. Stomata, the gas





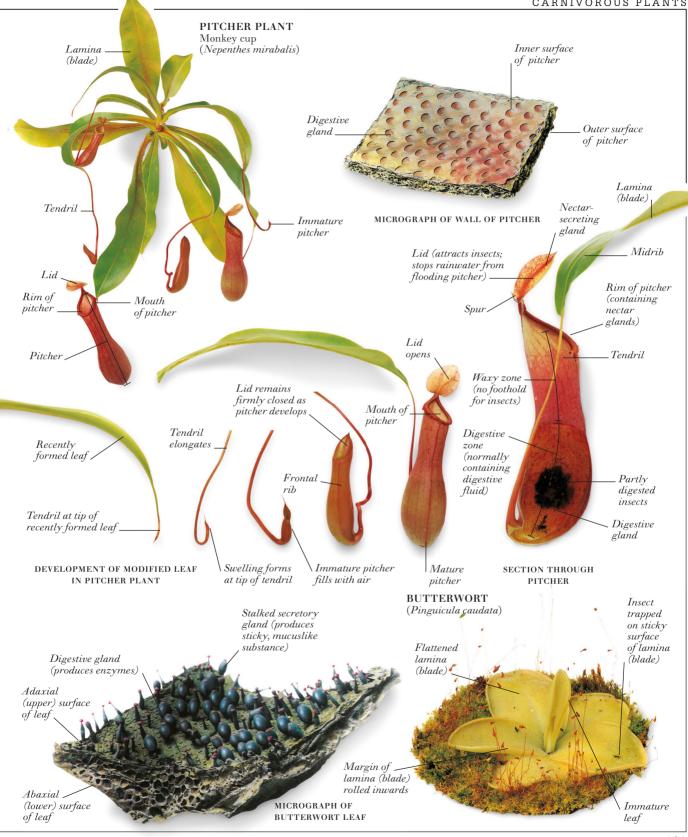


Trigger hair

MICROGRAPH OF LOBE OF

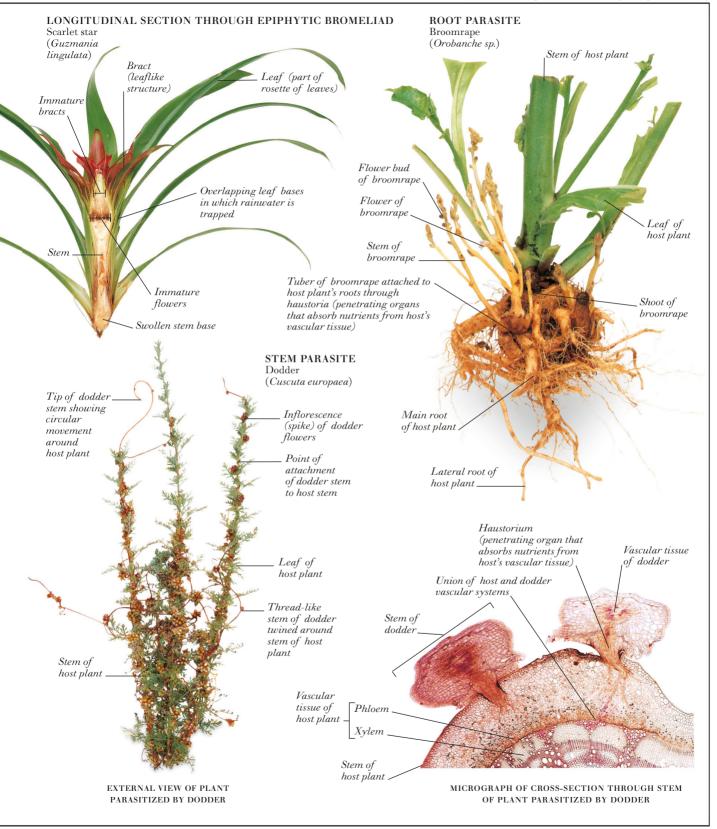
VENUS FLY TRAP

Tooth



Epiphytic and parasitic plants

EPIPHYTIC AND PARASITIC PLANTS GROW ON OTHER LIVING PLANTS. Typically, epiphytic plants are not rooted in the soil; instead, they live above ground level on the stems and branches of other plants. Epiphytes obtain water from trapped rainwater and from moisture in the air, and minerals from organic matter that has accumulated on the surface of the plant on which they are growing. Like other green plants, epiphytes produce their food by photosynthesis. Epiphytes include tropical orchids and bromeliads (air plants), and some mosses that live in temperate regions. Parasitic plants obtain all their nutrient requirements from the host plants on which they grow. The parasites produce haustoria, rootlike organs that penetrate the stem or roots of the host and grow inward to merge with the host's vascular tissue, from which the parasite extracts water, minerals, and manufactured nutrients. As they have no need to produce their own food, parasitic plants lack chlorophyll, the green photosynthetic pigment, and they have no foliage leaves. Partial parasitic plants (e.g., mistletoe) Inflorescence obtain water and minerals from the host plant but have (spike) Peduncle green leaves and stems and are therefore able to (inflorescence Flower stalk) produce their own food by photosynthesis. hud EPIPHYTIC ORCHID Strap-shaped Brassavola nodosa arching leaf (part of rosette Peduncle of leaves) (inflorescence Leaf margin with spines stalk) Flower Pedicel. Overlapping leaf (flower bases in which Mass of stalk) rainwater is trapped adventitious roots EPIPHYTIC BROMELIAD Aechmea miniata Bark of tree to Scale which epiphyte is attached leat Leaf Velamen Exodermis (multi-layered epidermis (outer layer capable of absorbing of cortex) water from rain or condensation) Cortex (layer between epidermis and vascular tissue) Aerial root Cortex cell containing Nodechloroplasts Pith Stem Vascular Xylem. Endodermis tissue (inner layer Phloemof cortex) Bark of tree to which epiphyte MICROGRAPH OF CROSS-SECTION THROUGH is attached AERIAL ROOT OF EPIPHYTIC ORCHID







ANIMALS

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Sponges, jellyfish, and sea anemones

SPONGES ARE MAINLY MARINE animals that make up the phylum Porifera. They are among the simplest of all animals, having no tissues or organs. Their bodies consist of two layers of cells separated by a

jellylike layer (mesohyal) that is strengthened by mineral spicules or protein fibers. The body is perforated by a system of pores and water channels called the aguiferous system. Special cells (choanocytes) with whiplike structures (flagella) draw water through the aquiferous system, thereby bringing tiny food particles to the sponge's cells. Jellyfish (class Scyphozoa), sea anemones (class Anthozoa), and corals (also class Anthozoa) belong to the SKELETON OF A SPONGE phylum Cnidaria, also known as Coelenterata. More complex than sponges, coelenterates have simple tissues, such as nervous tissue; a radially symmetrical body:

PARASITIC ANEMONE

Protein matrix

Pore

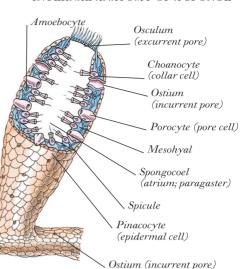
EXAMPLES OF SEA ANEMONES

and a mouth surrounded by tentacles with unique stinging

cells (cnidocytes).

(Calliactis parasitica) JEWEL ANEMONE (Corynactis viridis) PLUMOSE ANEMONE MEDITERRANEAN SEA ANEMONE (Metridium senile) (Condylactis sp.) GREEN SNAKELOCK ANEMONE (Anemonia viridis)

INTERNAL ANATOMY OF A SPONGE



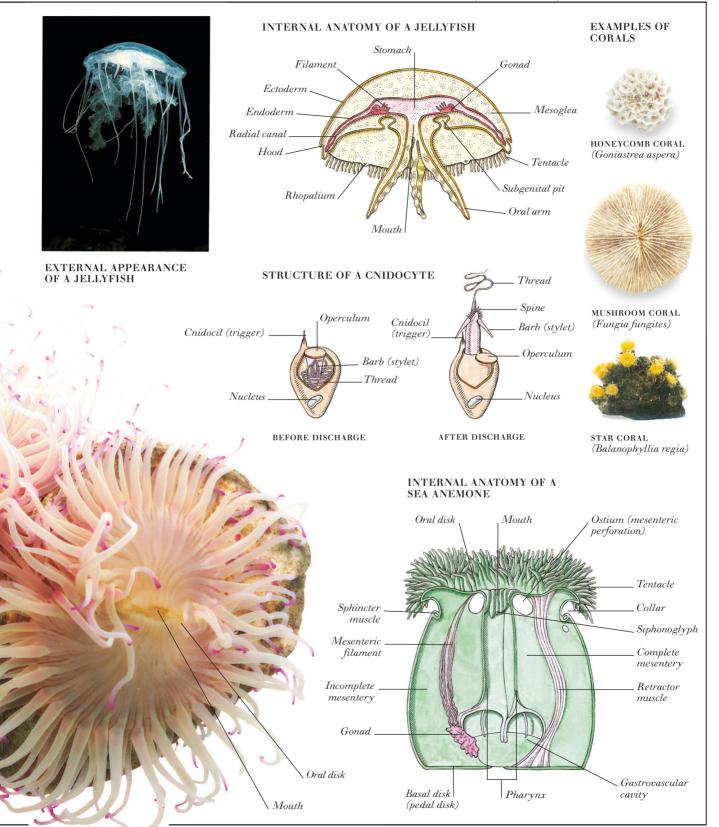
EXTERNAL FEATURES OF A SEA ANEMONE

Tentacle

BEADLET ANEMONI (Actinia equina)

GHOST ANEMONE (Actinothoe sphyrodeta)

Sagartia elegans





(CHRYSALIS)

EXTERNAL FEATURES

OF A BEETLE

Flagellum .

Compound.

Mandible

Head

Prothorax

Front leg

Labrum

Labial palp

The word insect refers to small invertebrate creatures. especially those with bodies divided into sections. Insects, including beetles, ants, bees, butterflies, and moths, belong to various orders in the class Insecta, which is a division of the phylum Arthropoda. Features common to all insects are an exoskeleton (external skeleton); three pairs of jointed legs; three body sections (head, thorax, and abdomen); and one pair of sensory antennae. Beetles (order Coleoptera) are the biggest group of insect, with about 300,000 species (about 30

percent of all known insects). They have a pair of hard elytra (wing cases), which are modified front wings. The principal function of the elytra is to protect the hind wings, which are used for flying. Ants, together with bees and wasps, form the order Hymenoptera, which contains about 200,000 species. This group is characterized by a marked narrowing between the thorax and abdomen. Butterflies and moths form the order Lepidoptera, which has about 150,000 species. They have wings covered with tiny scales, hence the name of their order (Lepidoptera means "scale wings"). The separation of lepidopterans into butterflies and moths is largely artificial, since there are no features that categorically distinguish one group from the other. In general, however, most butterflies fly by day, whereas most moths are night-flyers. Some insects, including butterflies and moths, undergo complete metamorphosis (transformation) during their life-cycle. A butterfly metamorphoses from an egg to a larva (caterpillar), then to a pupa (chrysalis), and finally to an imago (adult).

Tarsus

Femur

Trochante

Mesothorax

Scutellum Metathorax

Middle leg

Pedicel

Scape

Tibia

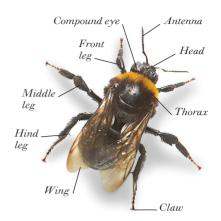
Elytron

Costal margin

Wing

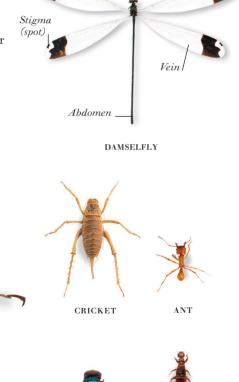
Abdomen

EXAMPLES OF INSECTS

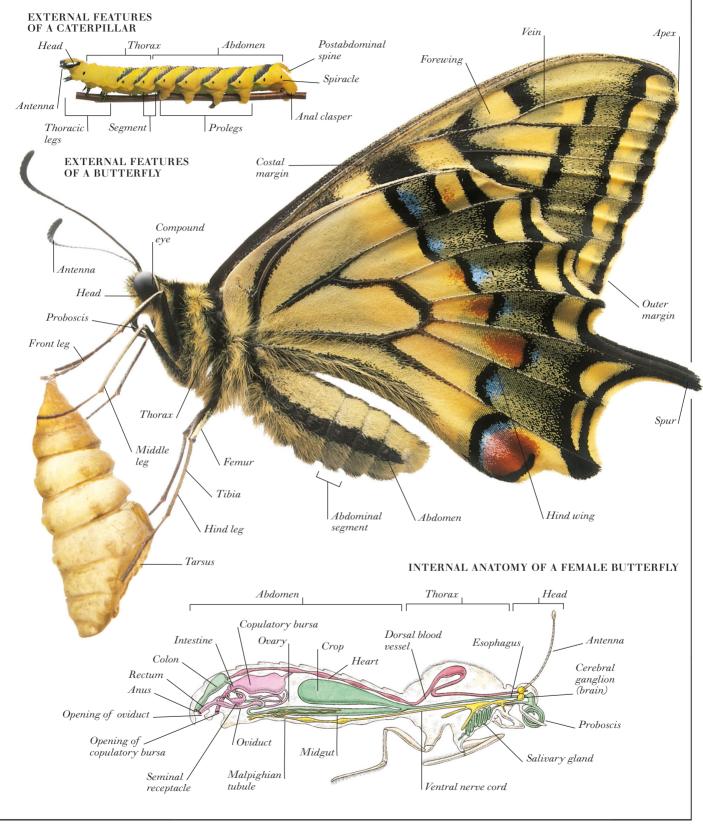


BUMBLEBEE

Compound



EARWIG



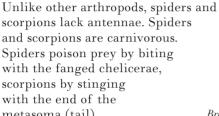
Arachnids

THE CLASS ARACHNIDA INCLUDES SPIDERS (order Araneae) and scorpions (order Scorpiones). The class is part of the phylum Arthropoda, which also includes insects and crustaceans.

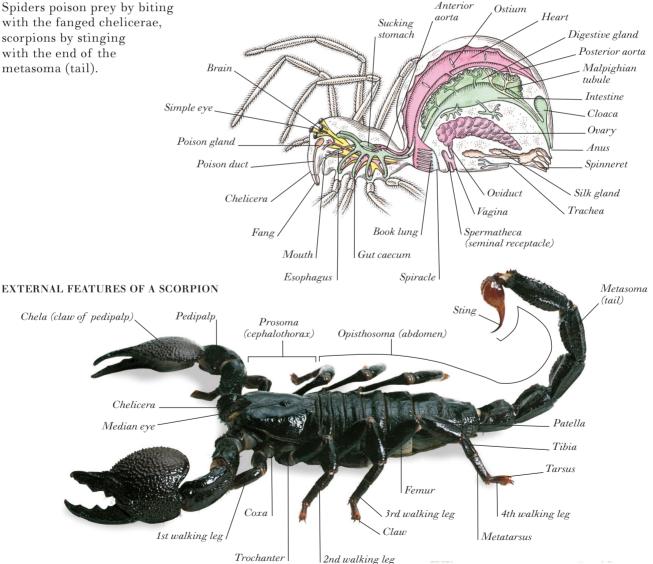
Spiders and scorpions are characterized by having four pairs of walking legs; a pair of pincerlike mouthparts called chelicerae; another pair of frontal appendages called pedipalps, which are sensory in spiders but used for grasping in scorpions; and a body divided into two sections (a combined head and thorax called a cephalothorax or prosoma, and an abdomen or opisthosoma).

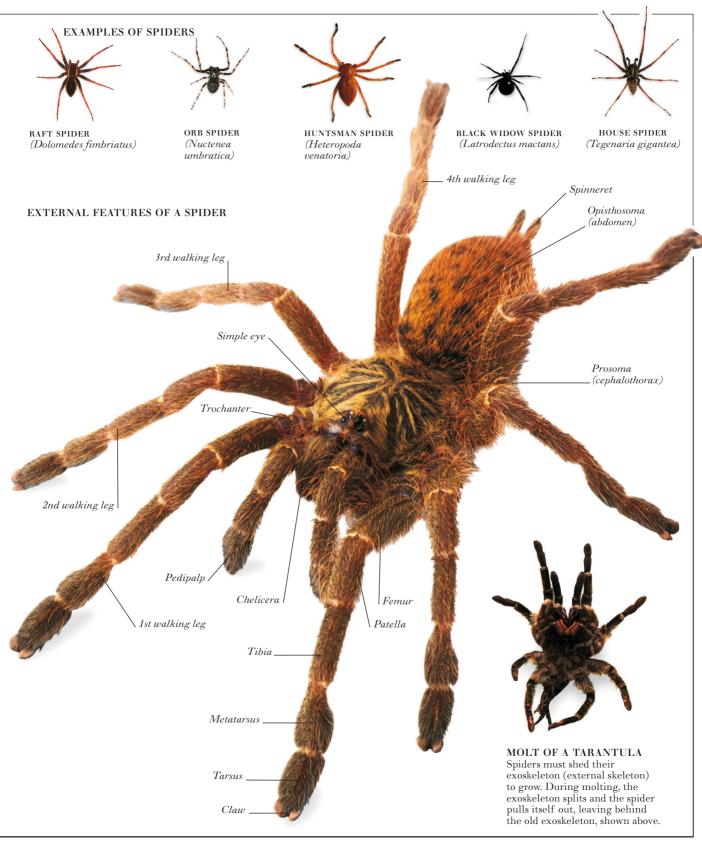


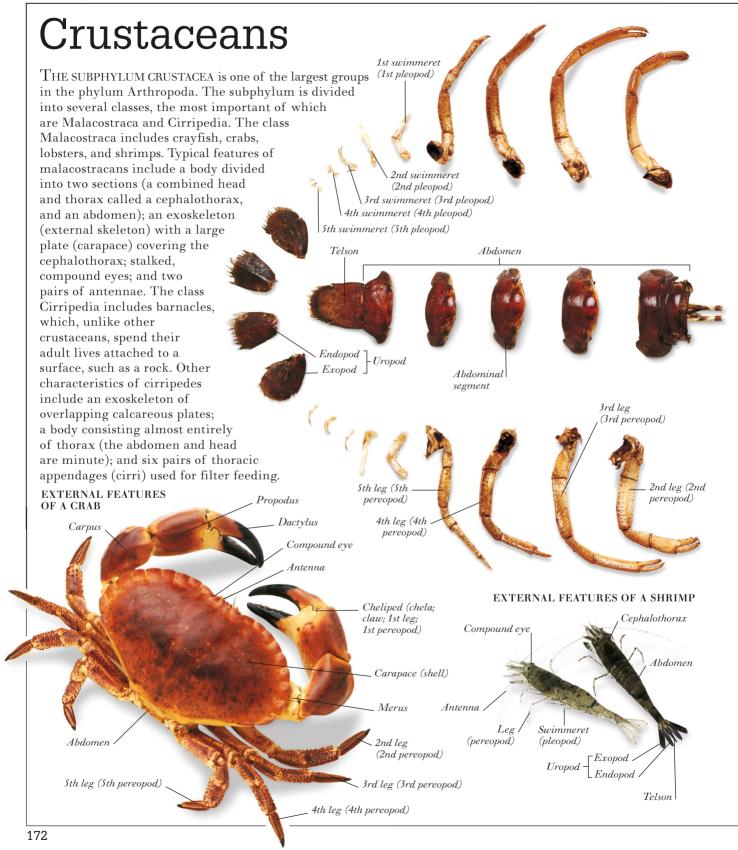
MEXICAN TRUE RED-LEGGED TARANTULA (Euathlus emilia)

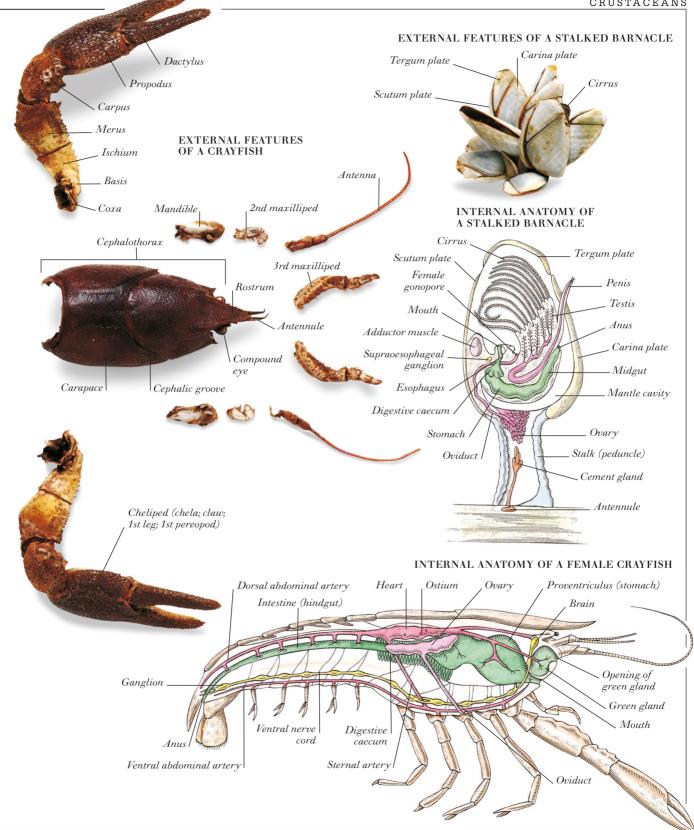


INTERNAL ANATOMY OF A FEMALE SPIDER

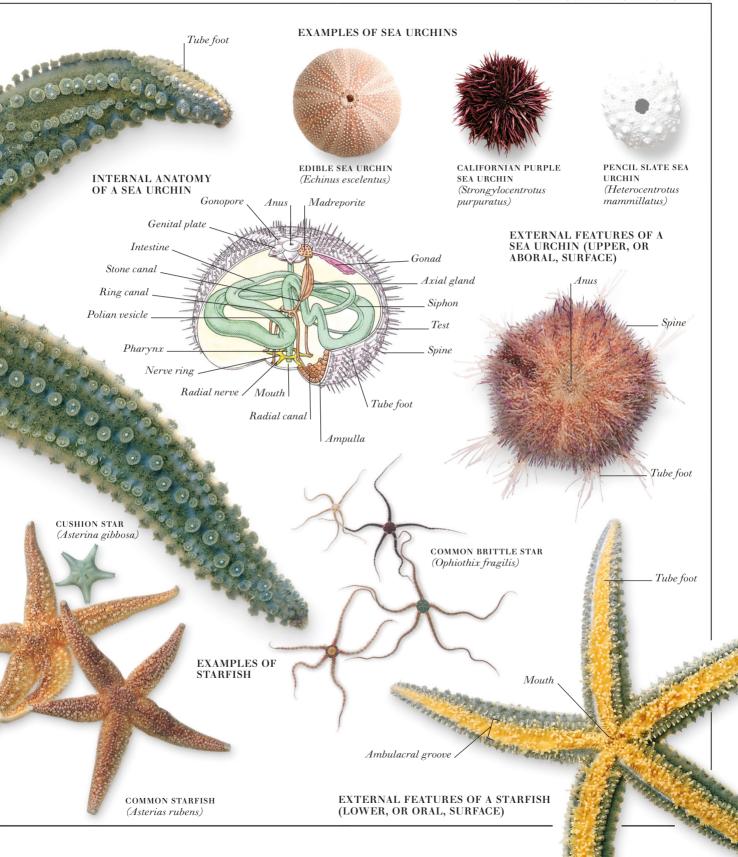






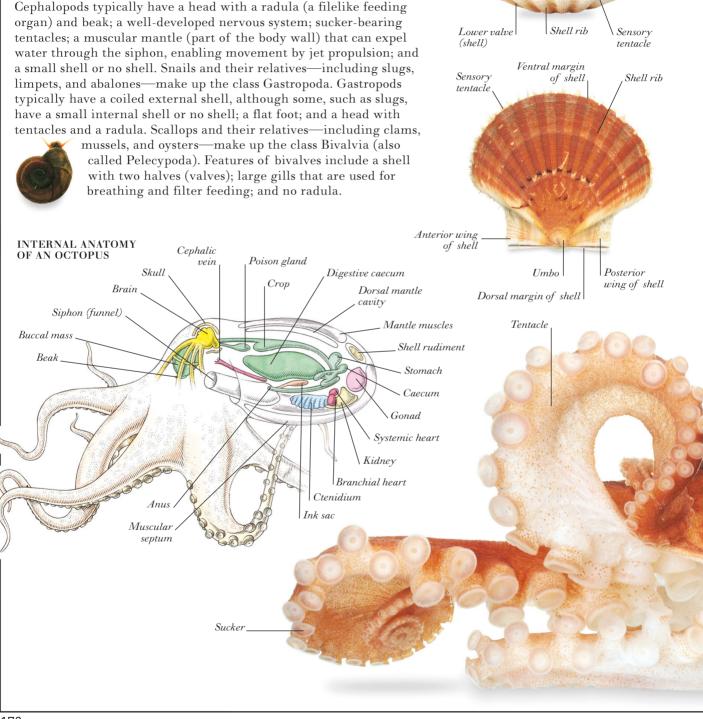


Conopore



Mollusks

THE PHYLUM MOLLUSCA (MOLLUSKS) is a large group of animals that includes octopuses, snails, and scallops. Octopuses and their relatives including squid and cuttlefish—form the class Cephalopoda. Cephalopods typically have a head with a radula (a filelike feeding

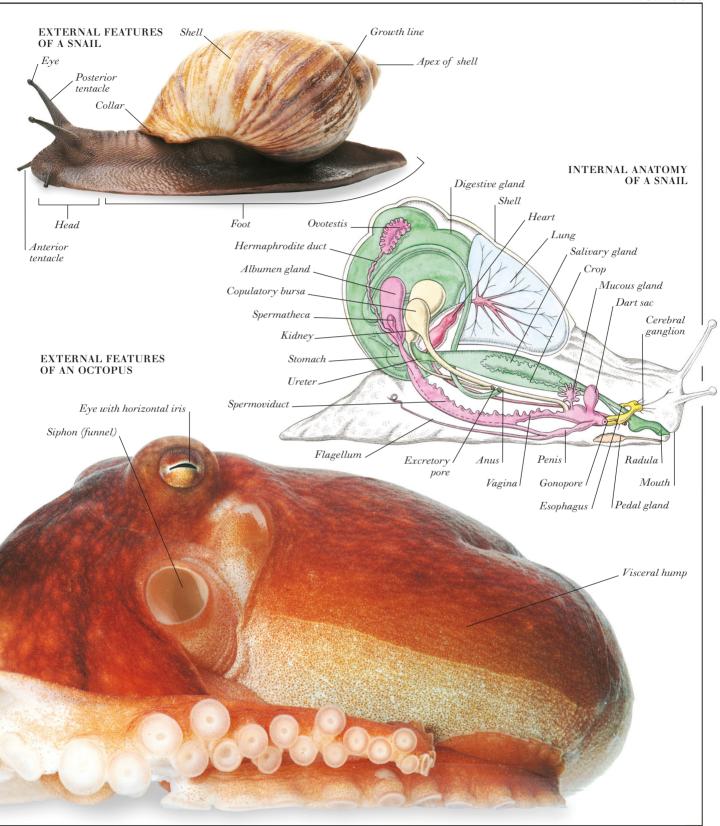


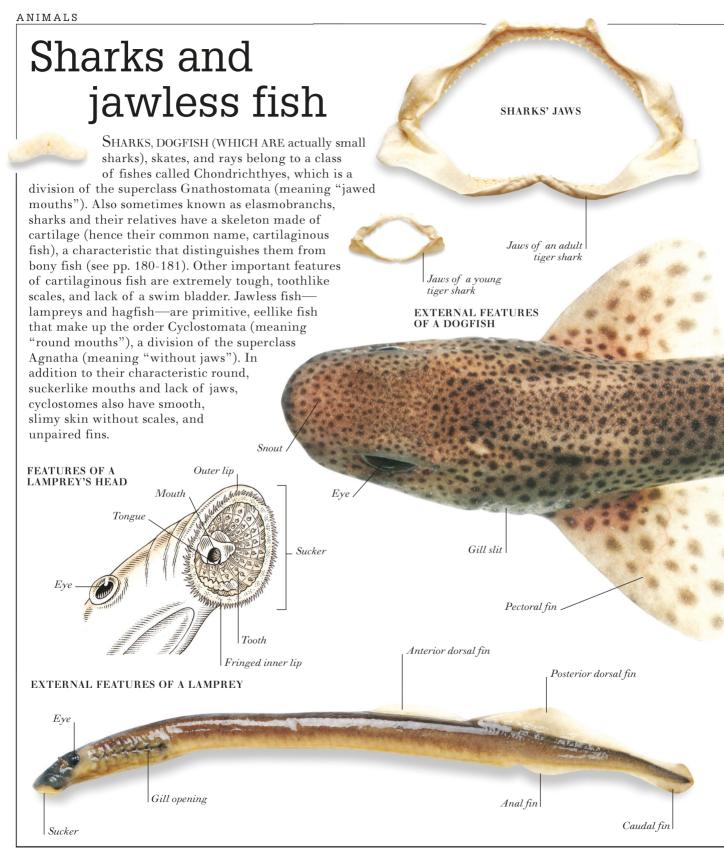
EXTERNAL FEATURES OF A SCALLOP

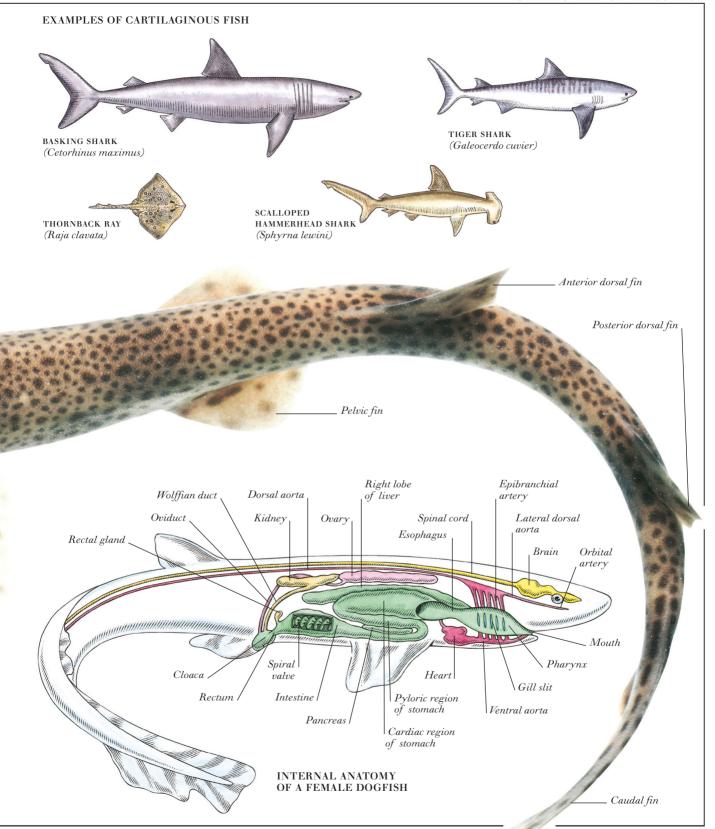
Ocellus (eye)

Mantle

Upper valve (shell)





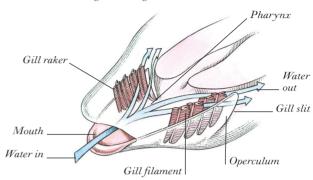


Bony fish

BONY FISH, SUCH AS CARP, TROUT, SALMON, perch, and cod, are by far the best known and largest group of fish, with more than 20,000 species (over 95 percent of all known fish). As their name suggests, bony fish have skeletons made of bone, in contrast to the cartilaginous skeletons of sharks, jawless fish, and their relatives (see pp. 178-179). Other typical features of bony fish include a swim bladder, which functions as a variable-buoyancy organ, enabling a fish to remain effortlessly at whatever depth it is swimming; relatively thin, bonelike scales; a flap (called an operculum) covering the gills; and paired pelvic and pectoral fins. Scientifically, bony fish belong to the class Osteichthyes, which is a division of the superclass Gnathostomata (meaning "jawed mouths").

HOW FISH BREATHE

Fish "breathe" by extracting oxygen from water through their gills. Water is sucked in through the mouth; simultaneously, the opercula close to prevent the water from escaping. The mouth is then closed, and muscles in the walls of the mouth, pharynx, and opercular cavity contract to pump the water inside over the gills and out through the opercula. Some fish rely on swimming with their mouths open to keep water flowing over the gills.



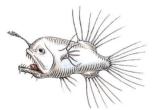
Vertebra

Radial cartilage

EXAMPLES OF BONY FISH



MANDARINFISH (Synchiropus splendidus)



ANGLERFISH (Caulophryne jordani)



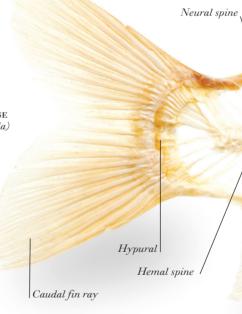
LIONFISH (Pterois volitans)



STURGEON (Acipenser sturio)



OCEANIC SEAHORSE (Hippocampus kuda)

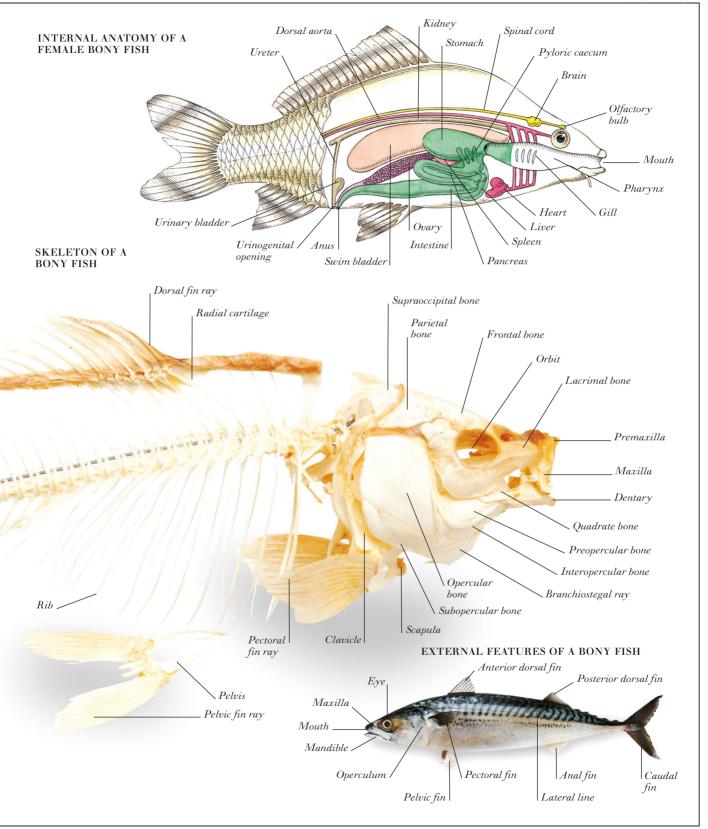




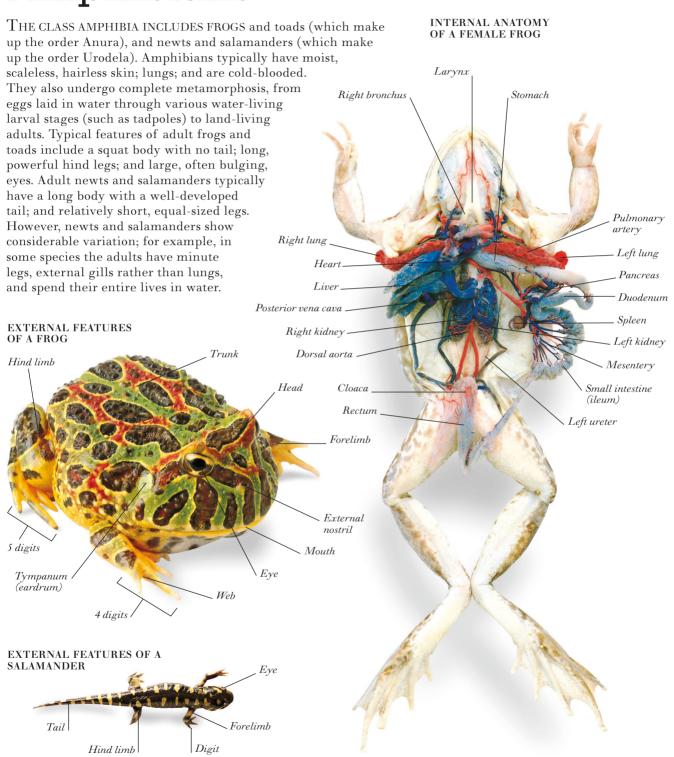
Anal fin ray

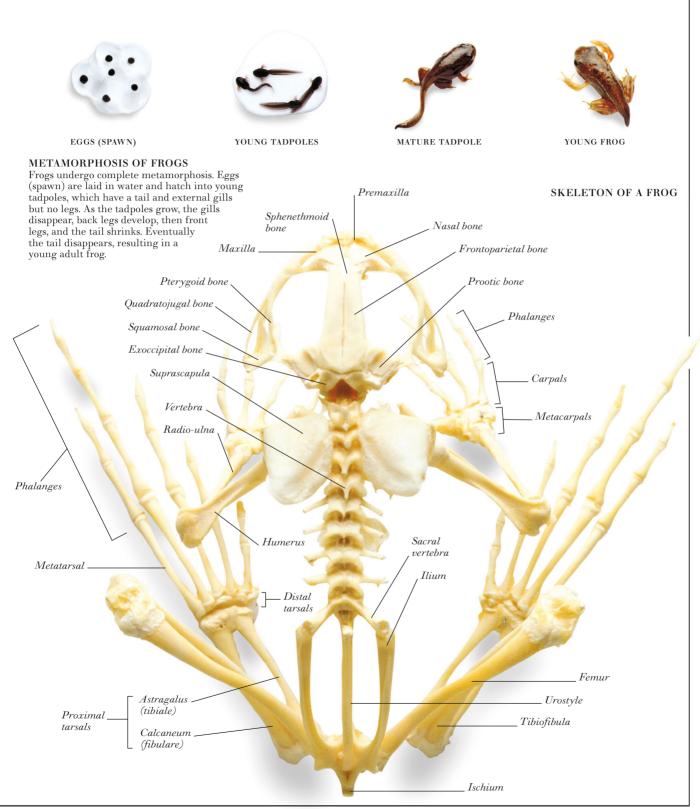


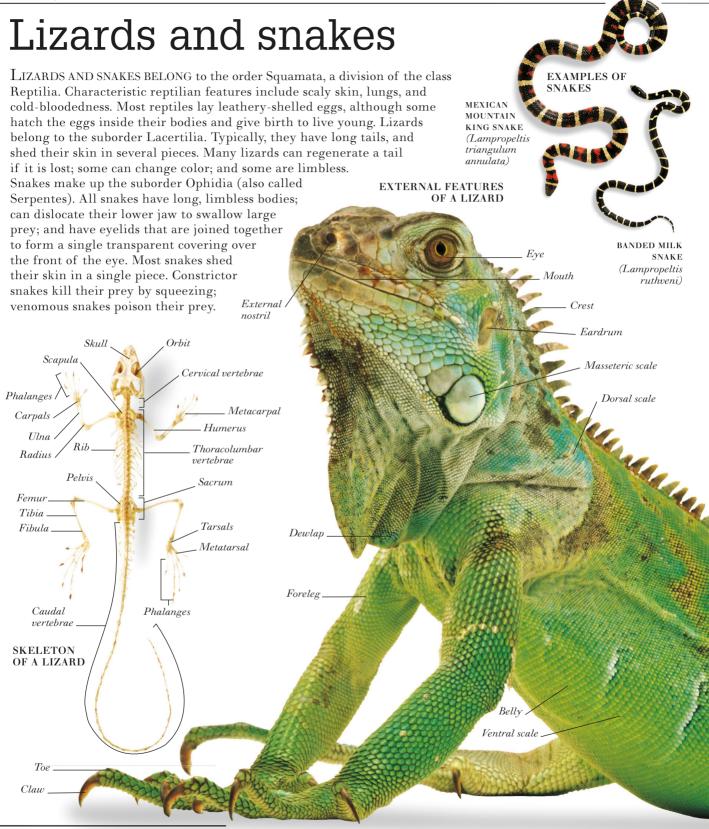
SNOWFLAKE MORAY EEL (Echidna nebulosa)

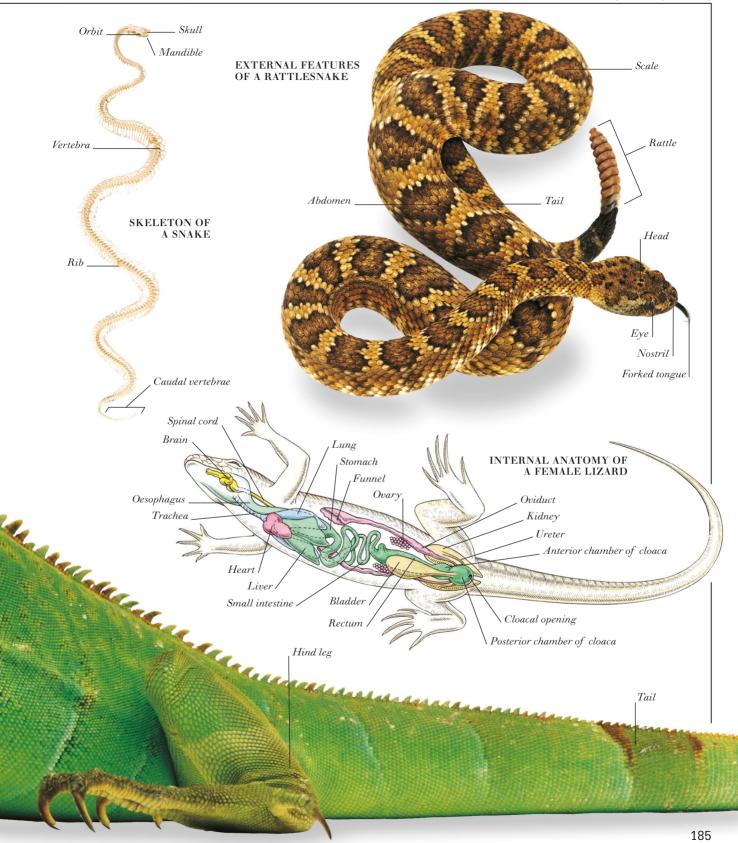


Amphibians









Crocodilians and turtles

CROCODILIANS AND TURTLES BELONG to different orders in the class Reptilia.

The order Crocodilia includes crocodiles, alligators, caimans, and gharials. Typically, crocodilians are carnivores (flesh-eaters), and have a long snout, sharp teeth for gripping prey, and hard, square scales. All

crocodilians are adapted to living on land and in water: they have four strong legs for moving on land; a powerful tail for swimming; and their

eyes and nostrils are high on the head so that they stay above water while

the rest of the body is submerged. The order Chelonia includes marine turtles, terrapins (freshwater turtles), and tortoises (land turtles).

Characteristically, chelonians have a short, broad body encased in a bony shell with an outer horny covering, into which the head and limbs

can be withdrawn; and a horny beak instead of teeth.

SKULLS OF CROCODILIANS



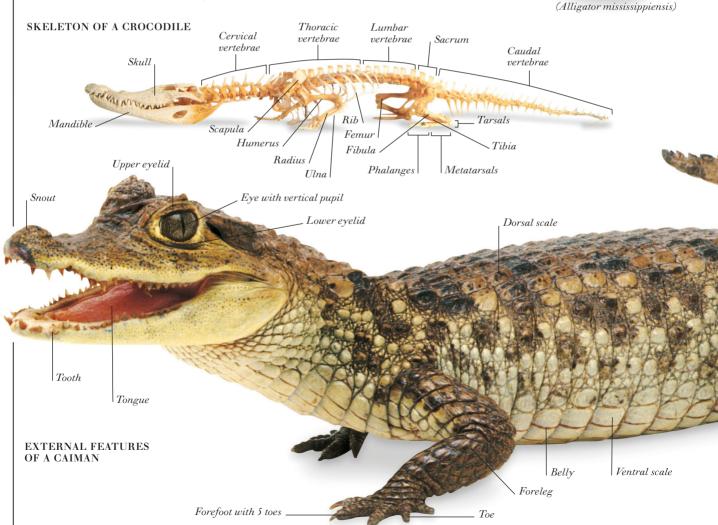
GHARIAL (Gavialis gangeticus)

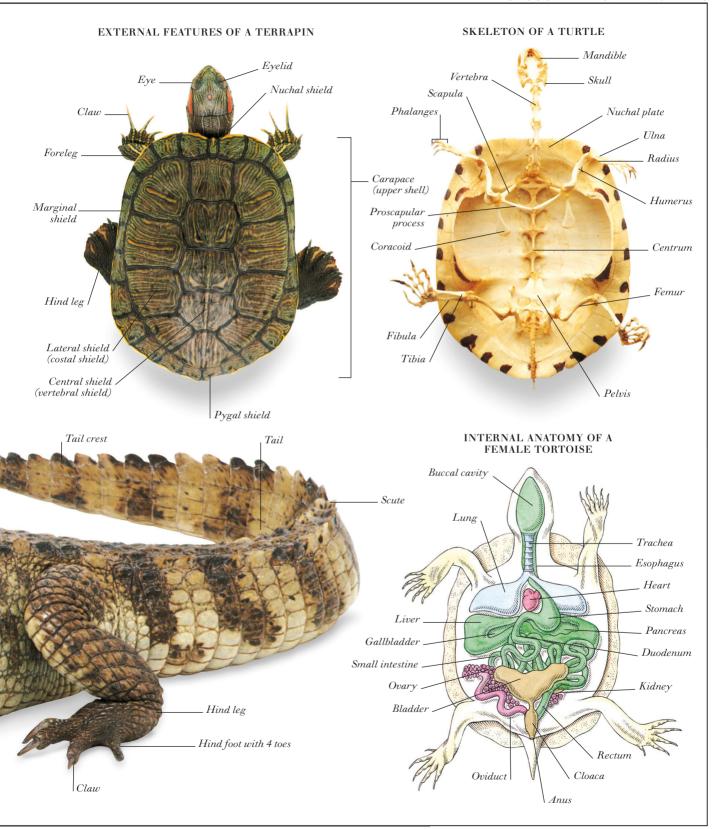


NILE CROCODILE (Crocodylus niloticus)



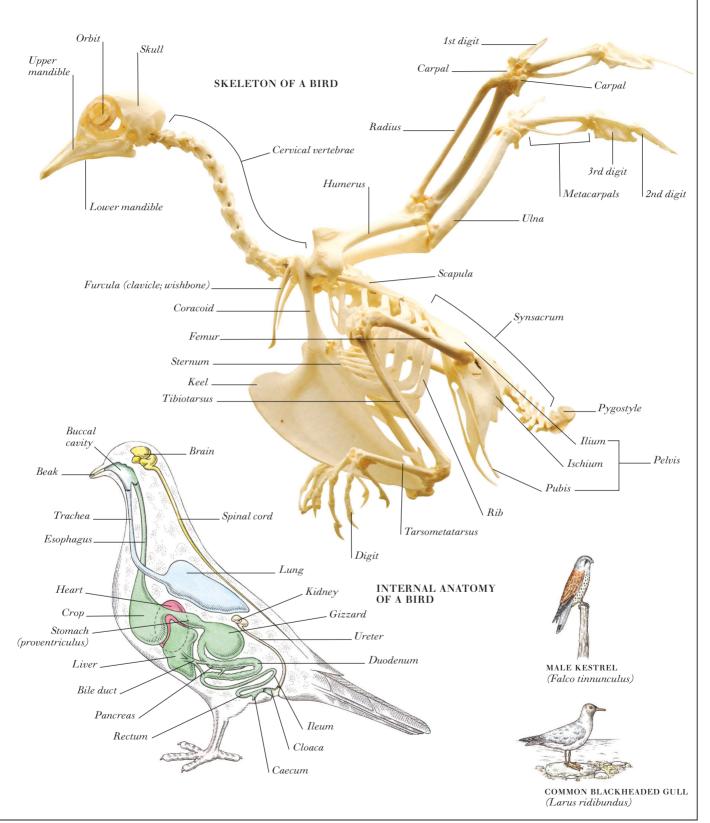
AMERICAN ALLIGATOR



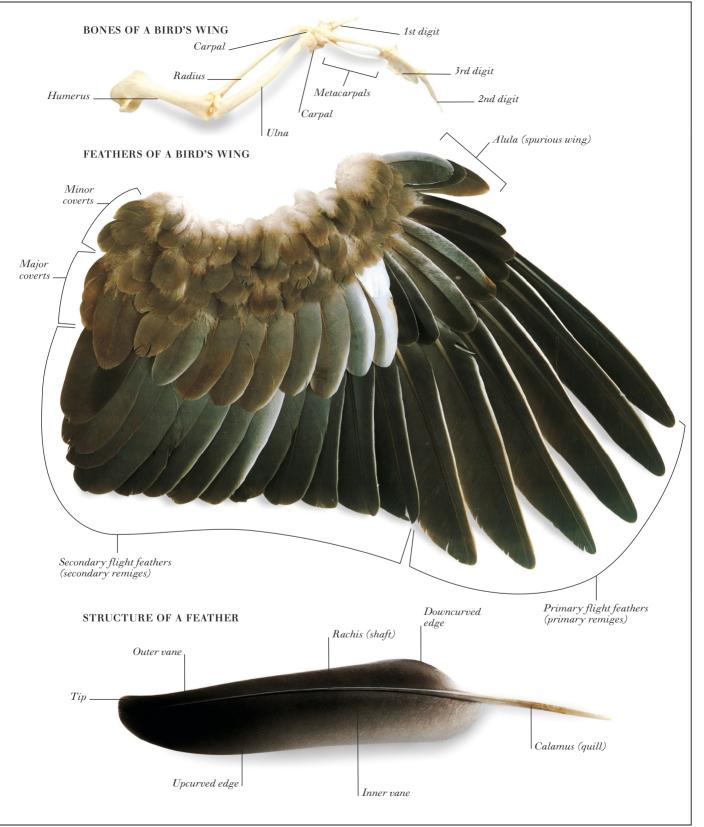


Birds 1

BIRDS MAKE UP THE CLASS AVES. There are more than 9,000 species, almost all of which can fly (the only flightless birds are penguins, ostriches, rheas, cassowaries, and kiwis). The ability to fly is reflected in the typical bird features: forelimbs modified as wings; a streamlined body; and hollow bones to reduce weight. All birds lay hard-shelled eggs, which the parents incubate. Birds' beaks and feet vary according to diet and way of life. Beaks range from general-purpose types suitable for a EXTERNAL FEATURES OF A BIRD mixed diet (those of thrushes, for example), to types Forehead specialized for particular foods (such as the large, Crown curved, sieving beaks of flamingos). Feet range Nostril from the webbed "paddles" of ducks, to the Uppertalons of birds of prev. Plumage also varies mandible widely, and in many species the male is NapeReak brightly colored for courtship display whereas the female is drab. Lower mandible Chin. EXAMPLES OF BIRDS Throat Minor Lesser wing coverts coverts. Median wing coverts MALE TUFTED DUCK (Aythya fuligula) Greater wing coverts (major coverts) Secondary flight feathers (secondary remiges) Breast Primary flight feathers (primaryremiges) Belly Flank WHITE STORK (Ciconia ciconia) Thigh Under tail Claw coverts Tarsus Toe Tail feathers (retrices) MALE OSTRICH (Struthio camelus)

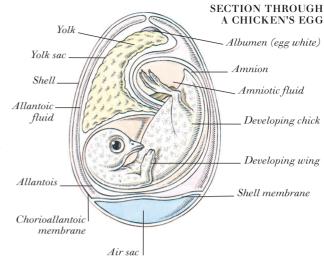


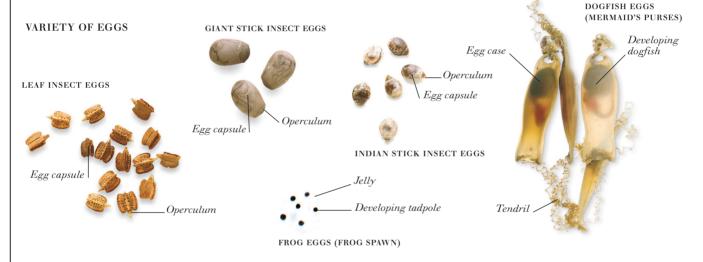




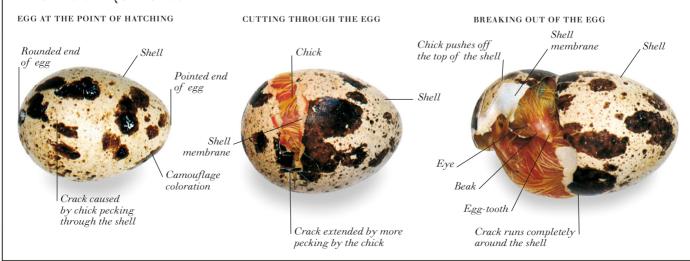
Eggs

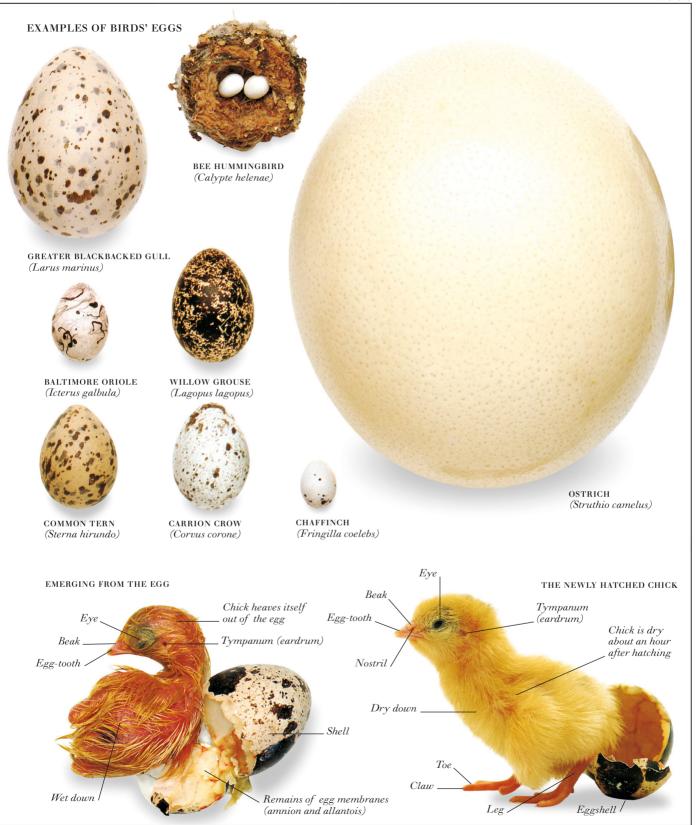
AN EGG IS A SINGLE CELL, produced by the female, with the capacity to develop into a new individual. Development may take place inside the mother's body (as in most mammals) or outside, in which case the egg has a protective covering such as a shell. Egg yolk nourishes the growing young. Eggs developing inside the mother generally have little yolk, because the young are nourished from her body. Eggs developing outside may also have little yolk if they are produced by animals whose young go through a larval stage (such as a caterpillar) that feeds itself while developing into the adult form. The shelled eggs of birds and reptiles contain enough yolk to sustain the young until it hatches into a juvenile version of the adult.





HATCHING OF A QUAIL'S EGG





Carnivores

THE MAMMALIAN ORDER CARNIVORA includes cats, dogs, bears, raccoons, pandas, weasels, badgers, skunks, otters, civets, mongooses, and hyenas. The order's name is derived from the fact that most of its members are carnivores (flesh-eaters). Typical carnivore features therefore reflect a hunting life-style: speed and agility; sharp claws and well-developed canine teeth for holding and killing prey; carnassial teeth (cheek teeth) for cutting flesh; and forward-facing eyes for good distance judgment. However, some members of the order—bears, badgers, and foxes, for examplehave a more mixed diet, and a few are entirely Vibrissa (whisker) herbivorous (plant-eating), notably pandas. Such animals have no carnassial teeth and tend to be slower moving than pure flesh-eaters.

Canine SKULL OF A LION tooth Nasal bone Zygomatic arch Incisor Maxilla Coronoid process tooth Orbit Sagittal crest Upper premolars Upper canine Lower canine Mandible Occipital Lower premolars condyle Condyle Tympanic Upper carnassial tooth Angular process bulla (4th upper premolar) SKULL OF A BEAR Sagittal crest Upper molars Zygomatic arch Orbit Nasal bone Occipital condyle Upper premolars MaxillaUpper canine



EXTERNAL FEATURES

Nostril

Tongue

Mandible

Lower premolars

Lower molars

Tympanic bulla

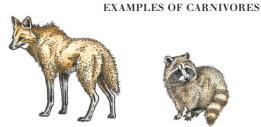
Angular

process

Condyle



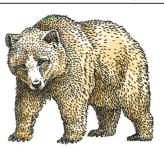
ALSATIAN DOG (Canis familiaris)



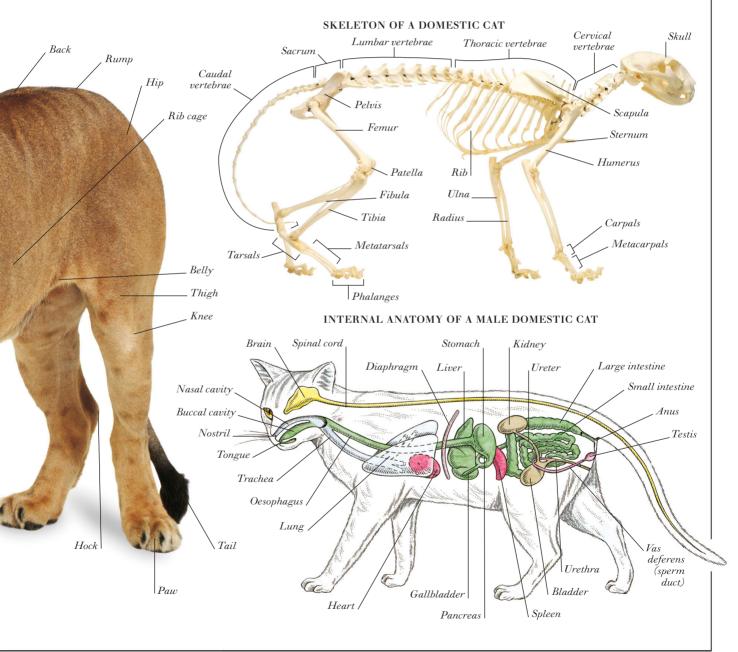
MANED WOLF (Chrysocyon brachyurus)



(Procyon lotor)



AMERICAN BLACK BEAR (Ursus americanus)



Rabbits and rodents

INTERNAL ANATOMY OF

Brain

A MALE RABBIT

Nasal

cavity

Mouth

Buccal

cavity

Tongue

Esophagus

Trachea

Lung

ALTHOUGH RABBITS AND RODENTS belong to different orders of mammals, they have some features in common. These features include chisel-shaped incisor teeth that grow continually, and eating their feces to extract more nutrients from their plant diet. Rabbits and hares belong to the order Lagomorpha. Characteristically, they have four incisors in the upper jaw and two in the lower jaw; powerful hind legs for jumping; forelimbs adapted for burrowing; long ears; and a small tail. Rodents make up the order Rodentia. This is the largest order of mammals, with more than 1,700 species, including squirrels, beavers, chipmunks, gophers, rats, mice, lemmings, gerbils, porcupines, cavies, and the capybara. Typical rodent features include two incisors in each jaw; OF A RABBIT short forelimbs for manipulating food; and cheek pouches for storing food.

Gallbladder

Liver

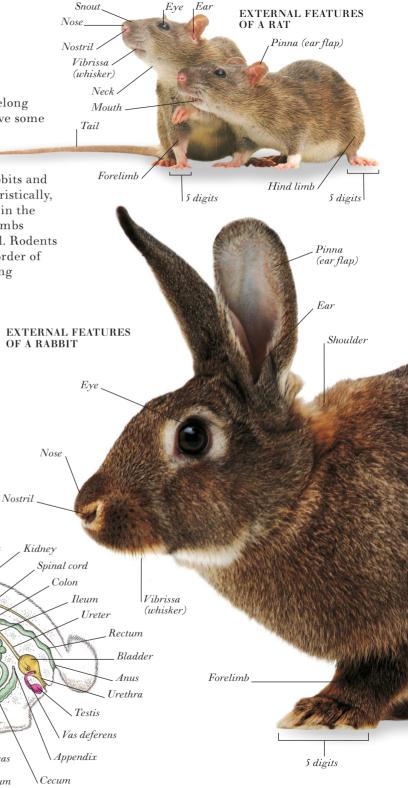
Diaphragm

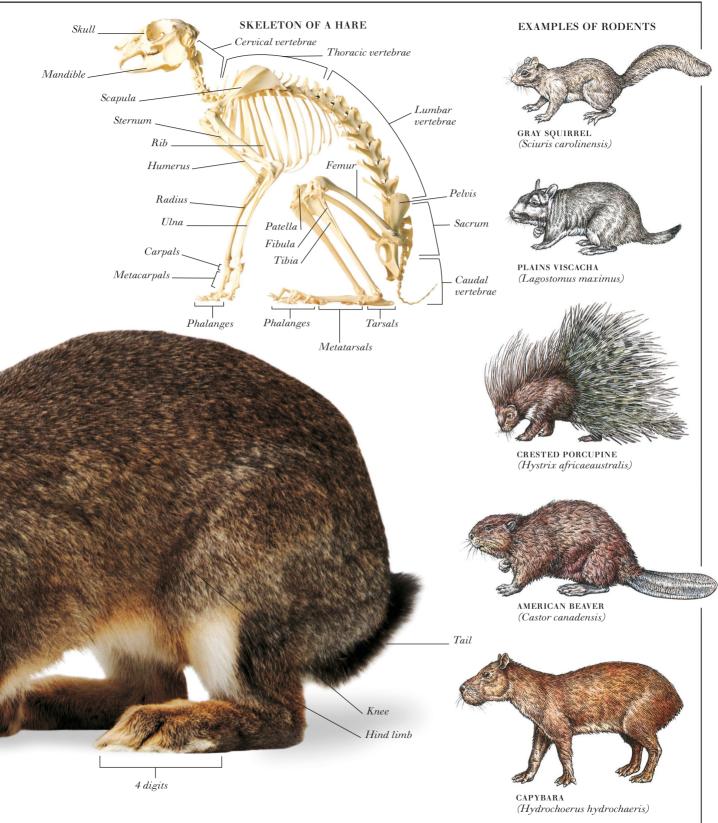
Heart

Stomach

Pancreas

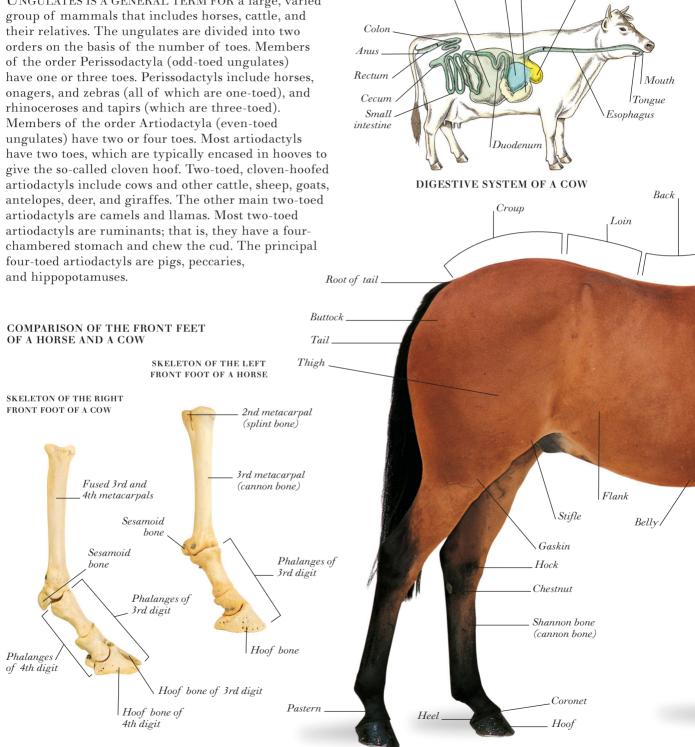
Duodenum





Ungulates

Ungulates is a general term for a large, varied group of mammals that includes horses, cattle, and Members of the order Artiodactyla (even-toed ungulates) have two or four toes. Most artiodactyls four-toed artiodactyls are pigs, peccaries,

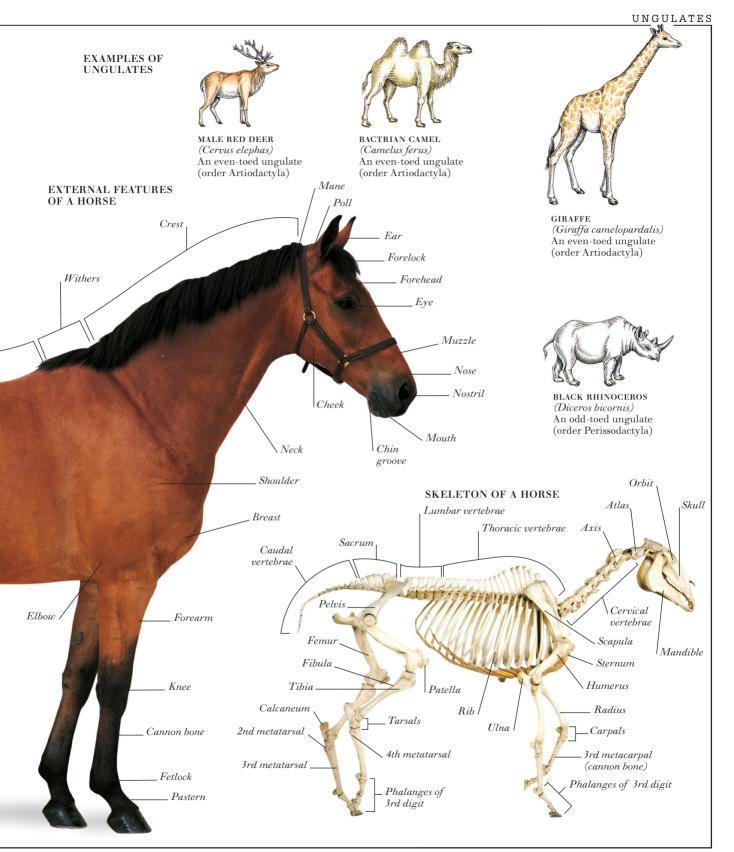


Chambers of stomach

Abomasum Reticulum

Omasum

Rumen



Elephants

THE TWO SPECIES OF elephant—African and Asian—are the only members of the mammalian order Proboscidea. The bigger African elephant is the largest land animal: a fully grown male may be up to 13 ft (4 m) tall and weigh nearly 8 tons (7 metric tons). A fully grown male Asian elephant may be 11 ft (3.3 m) tall and weigh 6 tons (5.4 metric tons). The trunk-an extension of the nose and upper lip—is the elephant's other most obvious feature. It is used for manipulating and lifting, feeding, drinking and spraying water, smelling, touching, and producing trumpeting sounds. Other characteristic features include a pair of tusks, used for defense and for crushing vegetation; thick, pillarlike legs and broad feet to support the massive body; and large ear flaps that act as radiators to keep the elephant cool.

Spinal cord

Epiglottis

Esophagus

Diaphragm

Nostril

Trachea

Lung

INTERNAL ANATOMY OF

Brain

A FEMALE ELEPHANT

Nasal cavity

Buccal cavity

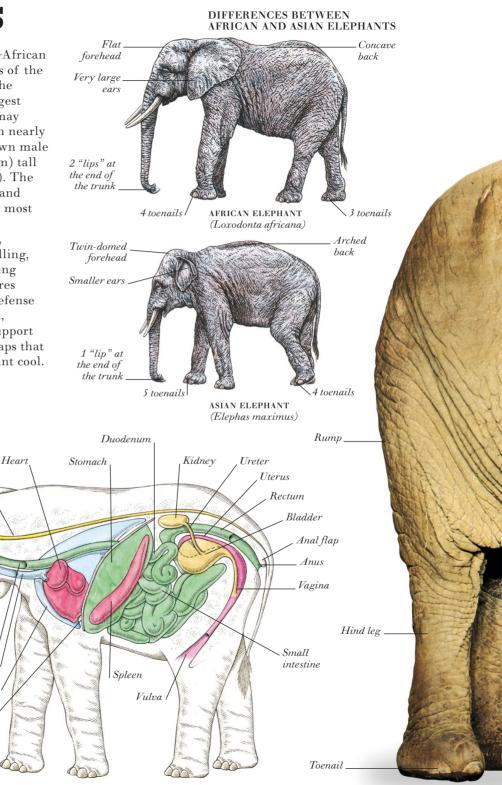
Mouth

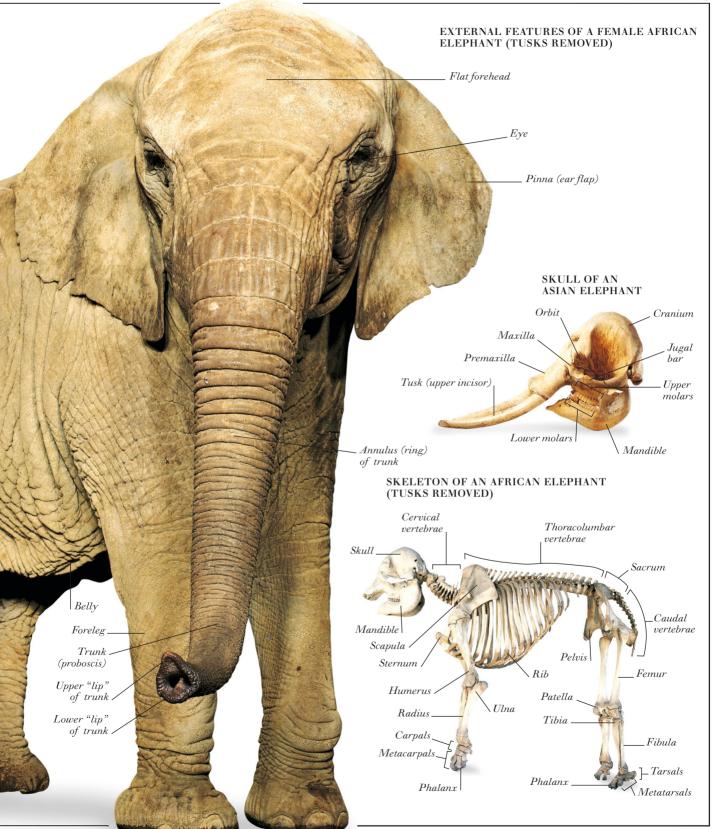
Tongue

Nasal

passage.

Tusk





Primates

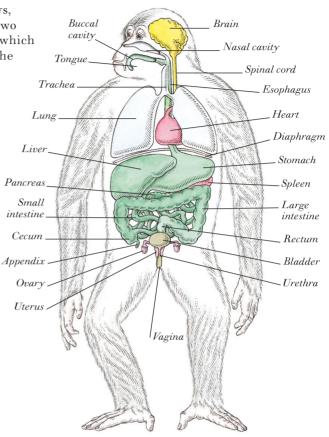
THE MAMMALIAN ORDER PRIMATES consists of monkeys, apes, and their relatives (including humans). There are two suborders of primates: Prosimii, the primitive primates, which include lemurs, tarsiers, and lorises; and Anthropoidea, the advanced primates, which include monkeys, apes, and humans. The anthropoids are divided into New World monkeys, Old World monkeys, and hominids. New World monkeys typically have wide-apart nostrils that open to the side; and long tails, which are prehensile (grasping) in some species. This group of monkeys lives in South America, and includes marmosets, tamarins, and howler monkeys. Old World monkeys typically have close-set nostrils that open forward or downward; and non-prehensile tails. This group of monkeys lives in Africa and Asia, and includes langurs, mandrills, macaques, and baboons. Hominids typically have large brains, and no tail. This group

includes the apes—chimpanzees, gibbons, gorillas,

and orangutans—and humans.

SKELETON OF A Skull RHESUS MONKEY Vagina Orbit Cervical vertebrae Mandible Thoracic vertebrae Clavicle Scapula SKULL OF A CHIMPANZEE RibTemporal bone Lumbar Humerus Suture Frontal bone vertebrae Parietal bone Supraorbital ridge Radius Orbit Sacrum UlnaMaxilla Occipital Premaxilla bone Carpals Patella Tibia Auditory Metacarpals Fibula meatus Incisor Pelvis toothZygomatic archPhalanges Canine Tarsals Mandible Molar Caudal Premolar tooth Metatarsals Phalanges vertebrae tooth tooth

INTERNAL ANATOMY OF A FEMALE CHIMPANZEE



EXAMPLES OF PRIMATES



RING-TAILED LEMUR (Lemur catta)
A prosimian



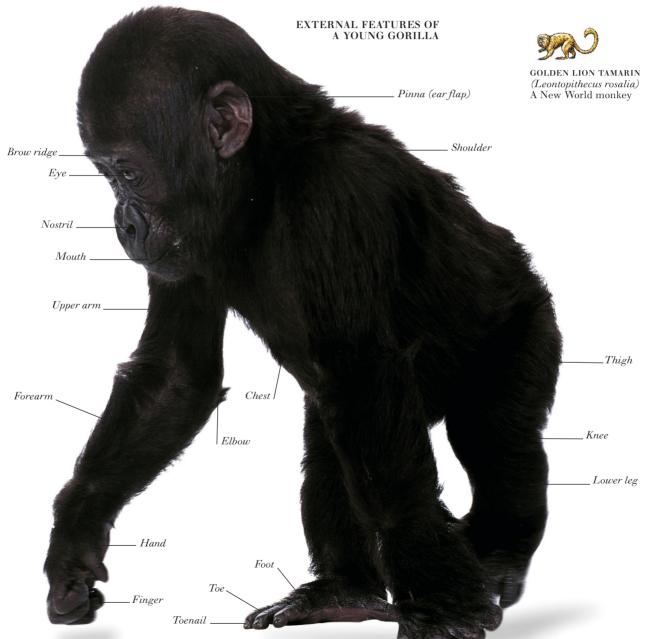
MALE RED HOWLER MONKEY
(Alouatta seniculus)
A New World monkey

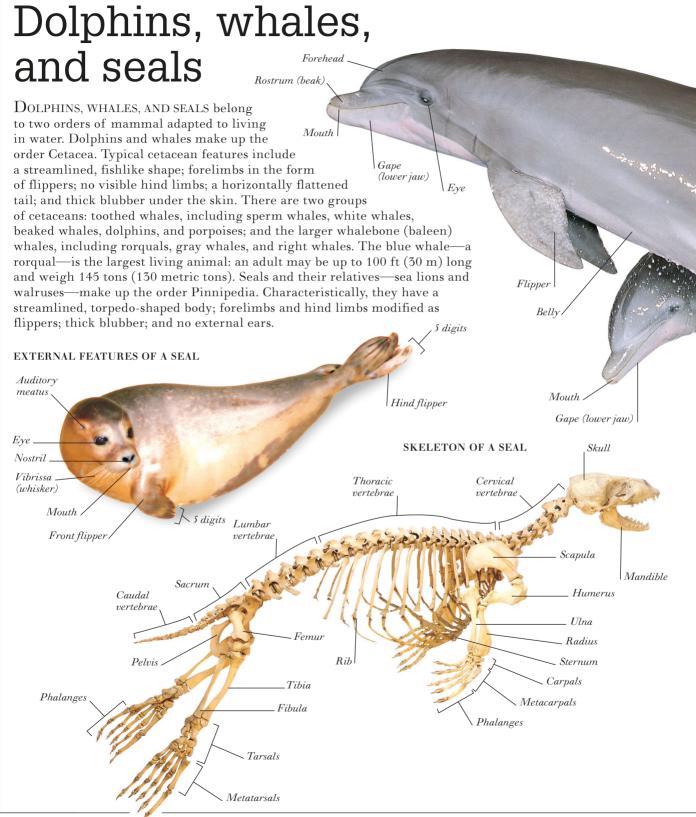


MALE MANDRILL (Mandrillus sphinx) An Old World monkey

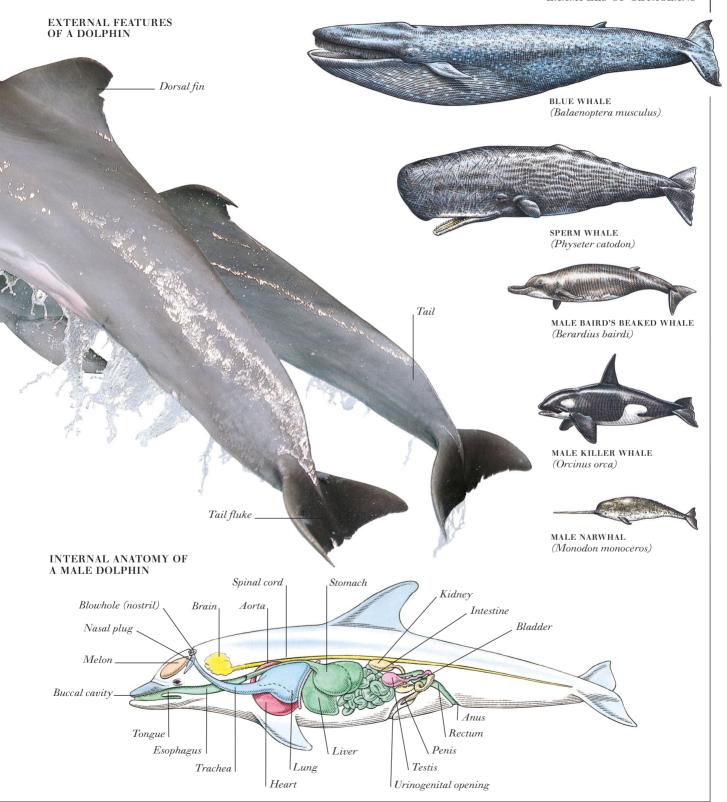


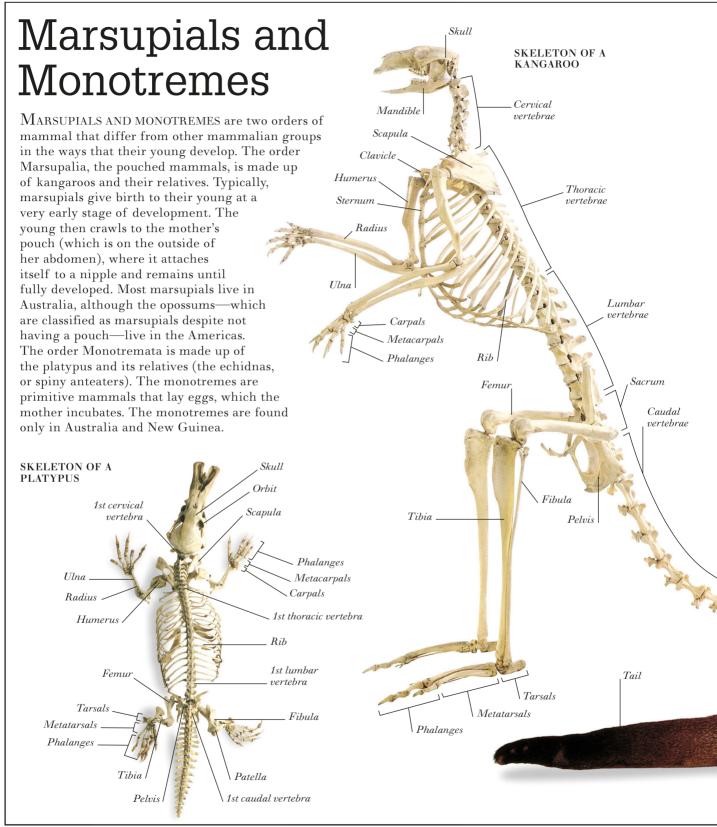
CHIMPANZEE (Pan troglodytes) An ape

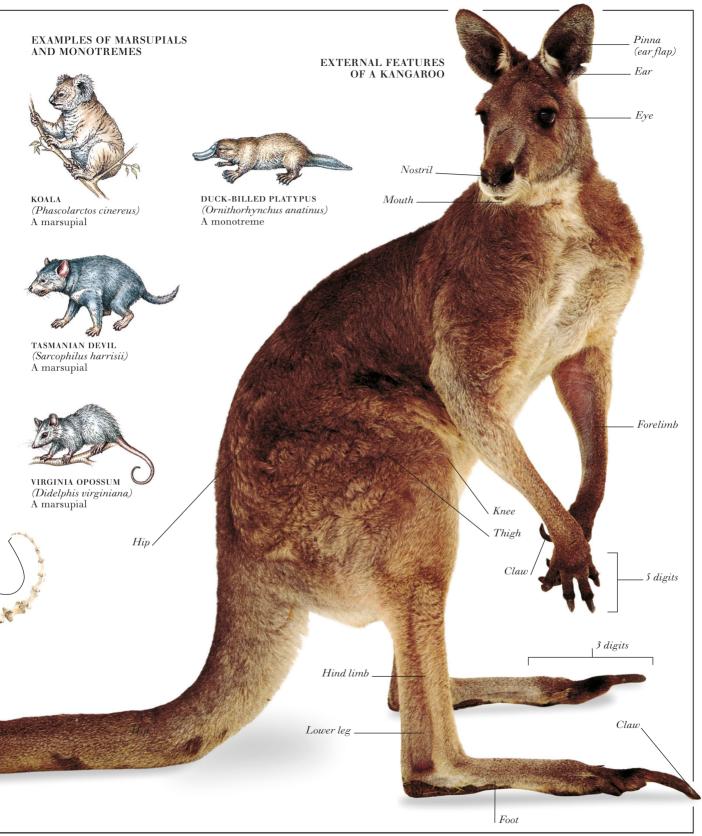


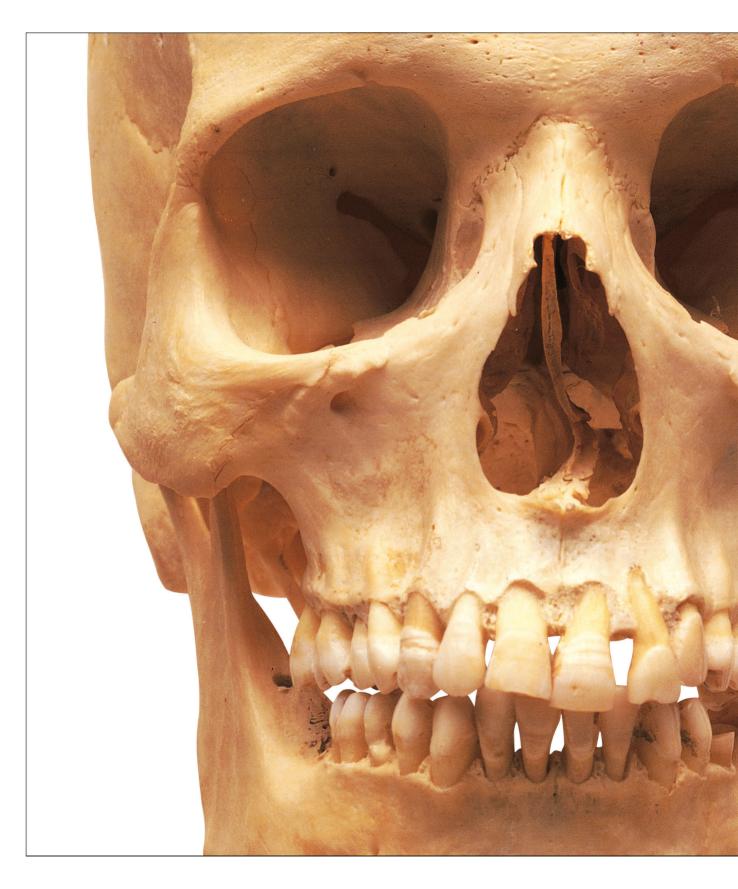


EXAMPLES OF CETACEANS





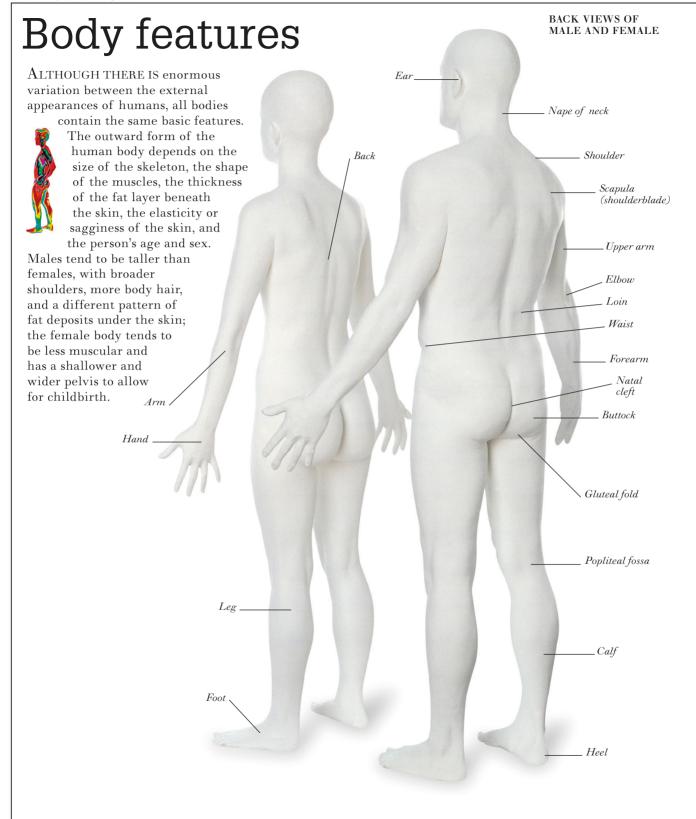


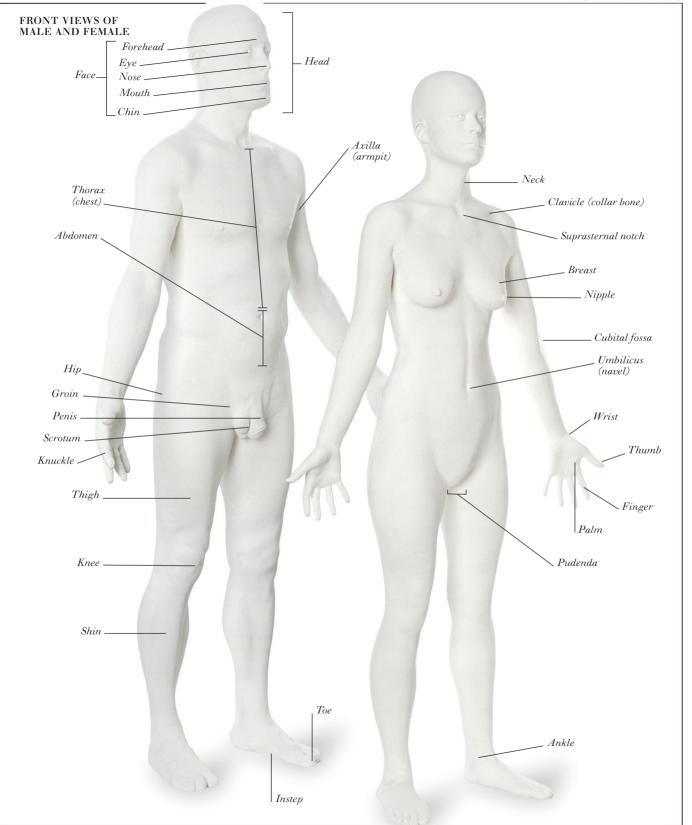




The Human Body

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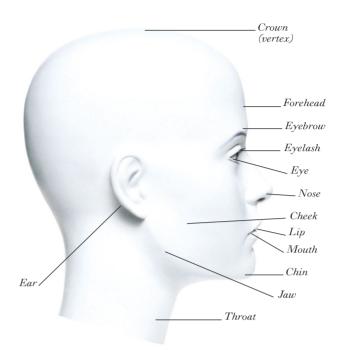




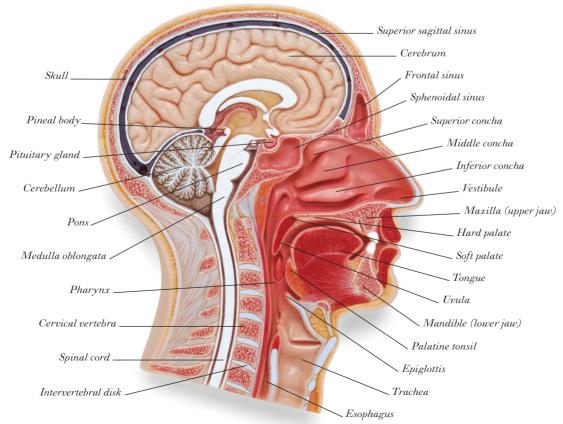
Head

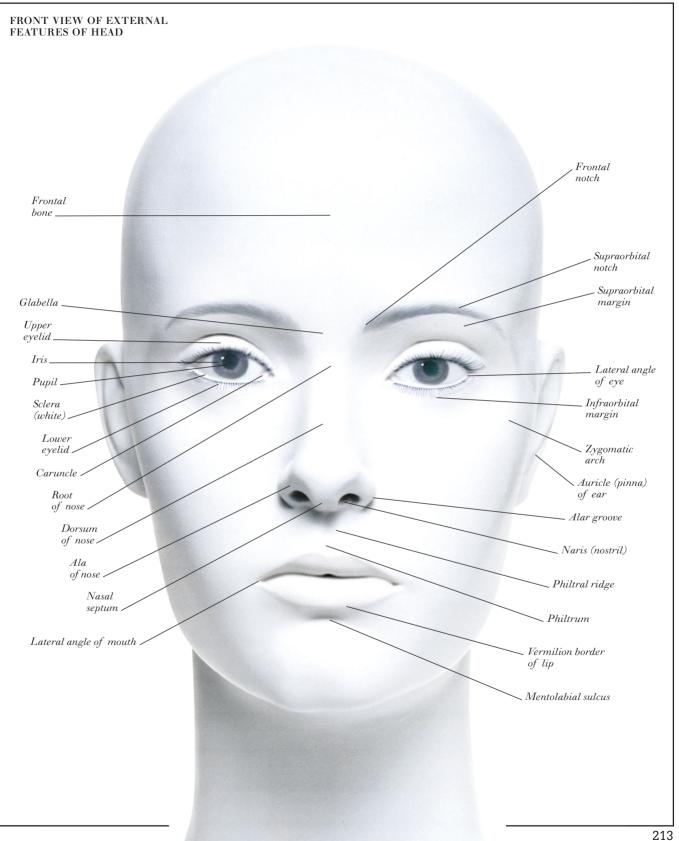
IN A NEWBORN BABY, the head accounts for one-quarter of the total body length; by adulthood, the proportion has reduced to one-eighth. Contained in the head are the body's main sense organs: eyes, ears, olfactory nerves that detect smells, and the taste buds of the tongue. Signals from these organs pass to the body's great coordination center: the brain, housed in the protective, bony dome of the skull. Hair on the head insulates against heat loss, and adult males also grow thick facial hair. The face has three important openings: two nostrils through which air passes, and the mouth, which takes in nourishment and helps form speech. Although all heads are basically similar, differences in the size, shape, and color of features produce an infinite variety of appearances.

SIDE VIEW OF EXTERNAL FEATURES OF HEAD



SECTION THROUGH HEAD





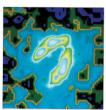
Body organs



ALL THE VITAL BODY ORGANS except for the brain are enclosed within the trunk or torso (the body apart from the head and limbs). The trunk contains two large cavities separated by a muscular sheet called the diaphragm. The upper

cavity, known as the thorax or chest cavity, contains the heart and lungs. The lower cavity, called the abdominal cavity, contains the stomach, intestines, liver, and pancreas, which all play a role in digesting food. Also within the trunk are the kidneys and bladder, which are part of the urinary system, and the reproductive organs, which hold the seeds of new human life. Modern imaging techniques, such as contrast X-rays and different types of scans, make it possible to see and study body organs without the need to cut through their protective coverings of skin, fat, muscle, and bone.

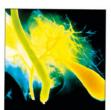
IMAGING THE BODY



SCINTIGRAM OF HEART CHAMBERS



ANGIOGRAM OF RIGHT LUNG



CONTRAST X-RAY OF GALLBLADDER



DOUBLE CONTRAST X-RAY OF COLON



ULTRASOUND SCAN
OF TWINS IN UTERUS



MAJOR INTERNAL

Thyroid gland

STRUCTURES

Right

lung

Diaphragm

Large

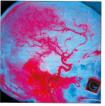
Small intestine

intestine

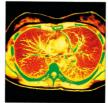
ANGIOGRAM OF KIDNEYS



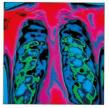
SCINTIGRAM OF NERVOUS SYSTEM



ANGIOGRAM OF ARTERIES OF HEAD



CT SCAN THROUGH FEMALE CHEST



THERMOGRAM OF CHEST REGION



ANGIOGRAM OF ARTERIES OF HEART



Greater omentum Heart

Left

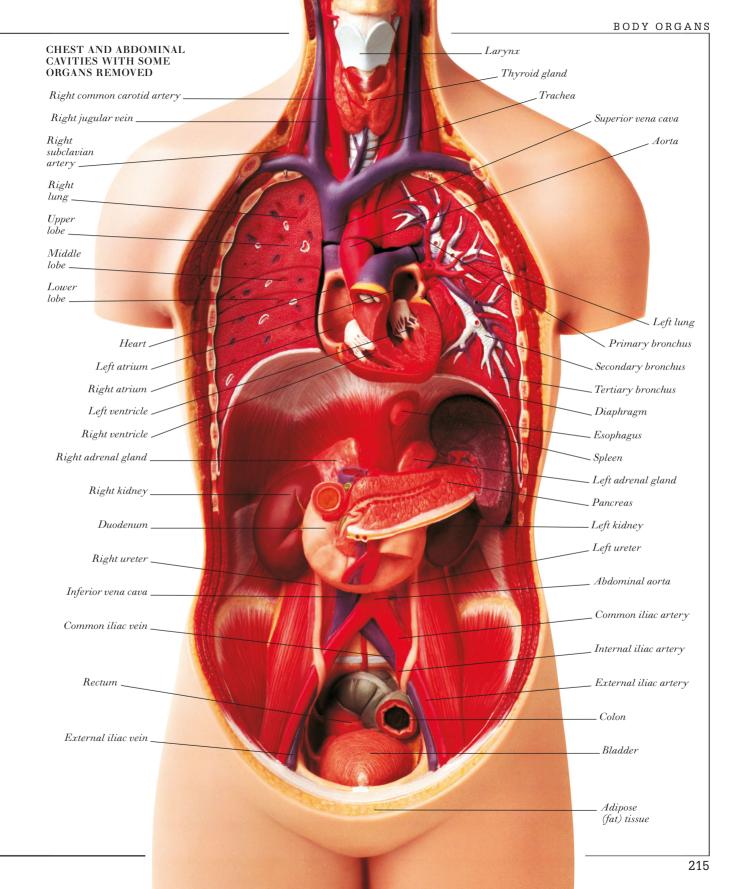
lung

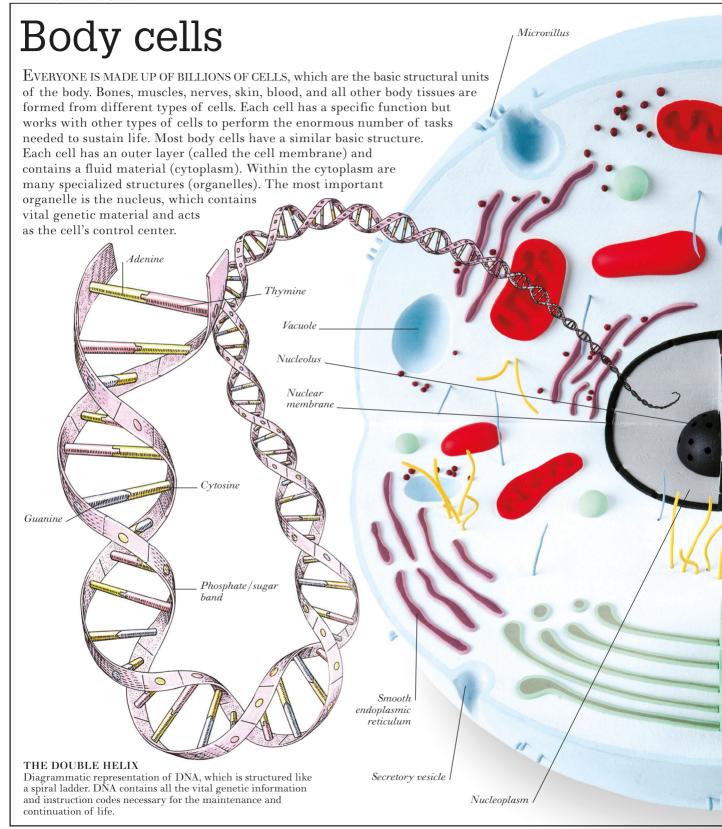
Liver

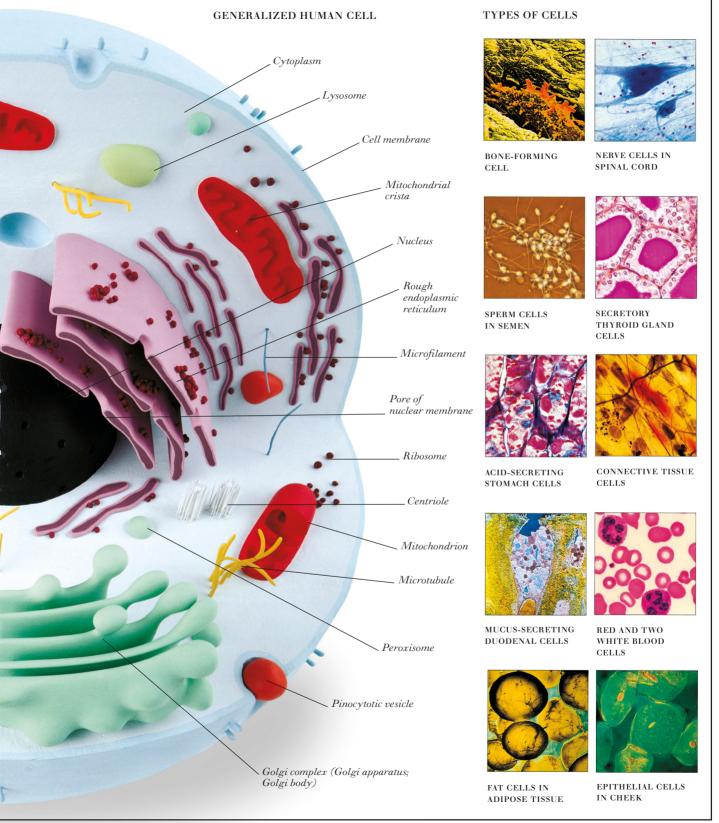
Stomach

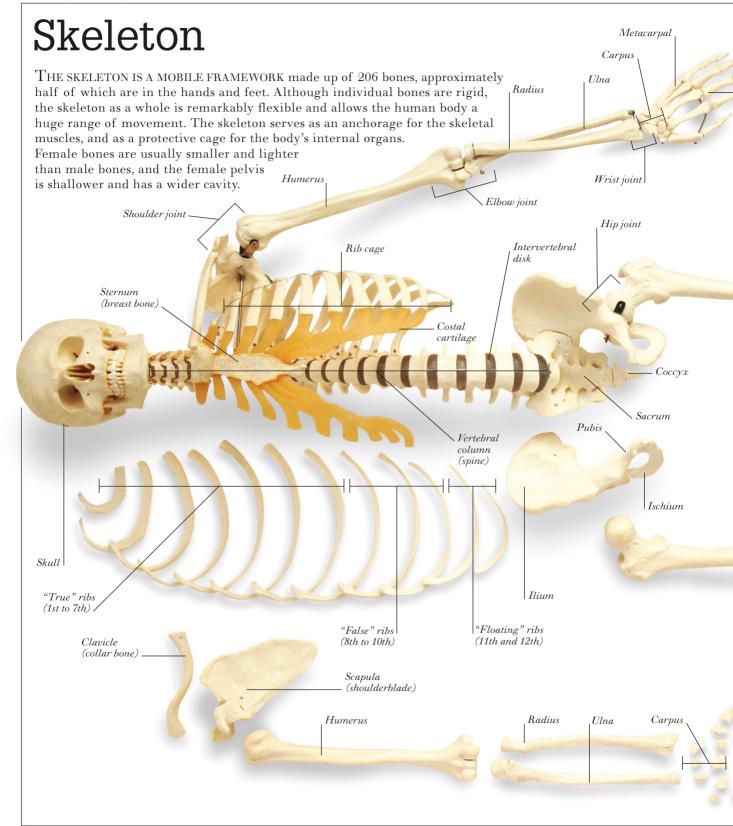
MRI SCAN THROUGH HEAD AT EYE LEVEL

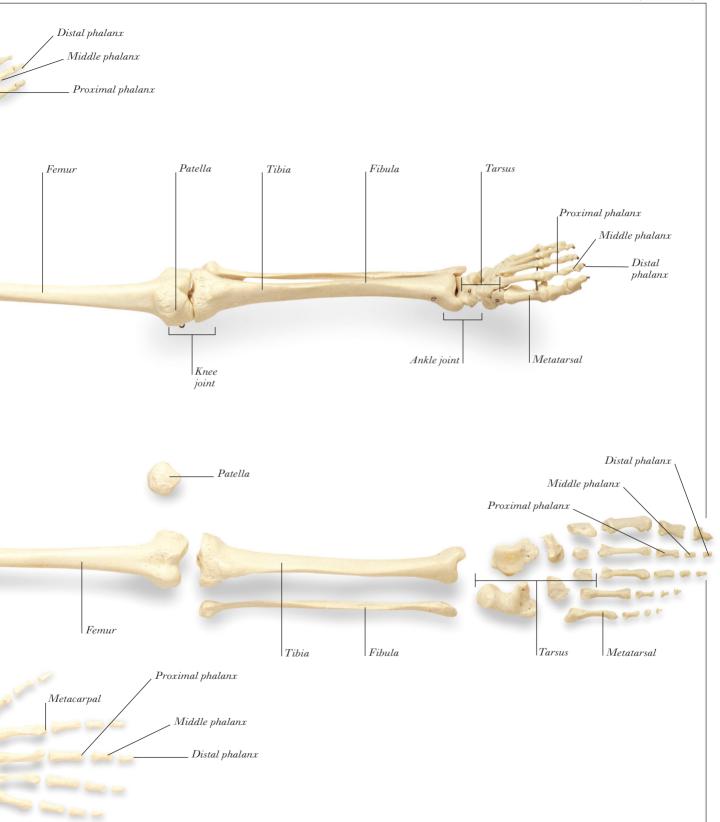




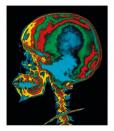








Skull



RIGHT SIDE VIEW OF SKULL

Greater wing of sphenoid bone

Parietal bone

Squamous

Lambdoid 1

Occipital bone

Temporal bone. External

auditory meatus.

Mastoid process

suture

suture

THE SKULL is the most complicated bony structure of the body but every feature serves a purpose. Internally, the main hollow chamber of the skull has three levels that support the brain, with Anterior fontanelle every bump and hollow corresponding to the shape of the brain. Underneath and toward Parietal the back of the skull is a large round hole, the foramen magnum, through which the spinal

Frontal bone

suture

Frontozygomatic

Orbital

Nasal bone

Maxilla

Mandible (lower

Concha

iaw)

Styloid process

Zygomatic arch

Mandible (lower jaw)

Posterior border.

of vomer

(upper jaw)

cavity

suture

cord passes. To the front of this are many smaller openings through which nerves, arteries, and veins pass to and from the brain. The roof of the skull is formed from four thin, curved bones that are firmly fixed together from the age of about two years. At the front of the skull are the two orbits, which contain the eyeballs, and a central hole for the airway of the nose. The jaw bone hinges on either side at ear level.

Coronal suture

Condyle

Coronoid

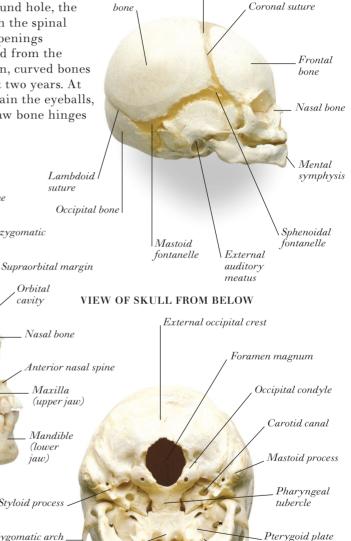
process

Zygomatic

bone

Mental foramen

RIGHT SIDE VIEW OF A FETAL SKULL



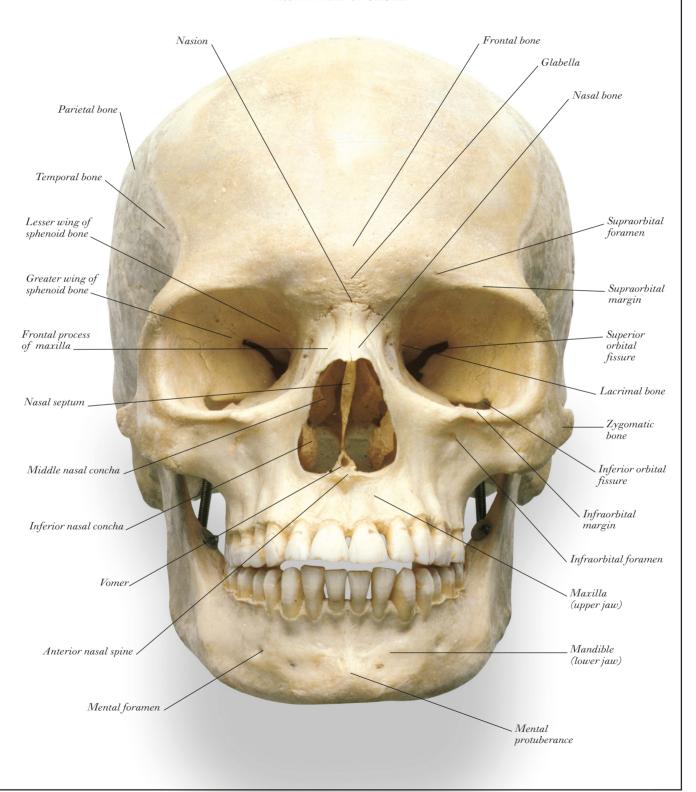
Pterygoid hamulus

Greater palatine

foramen

Posterior nasal aperture

FRONT VIEW OF SKULL

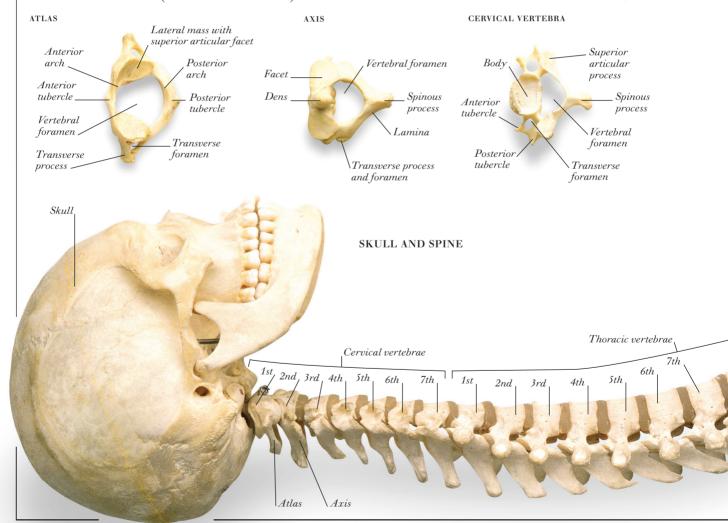


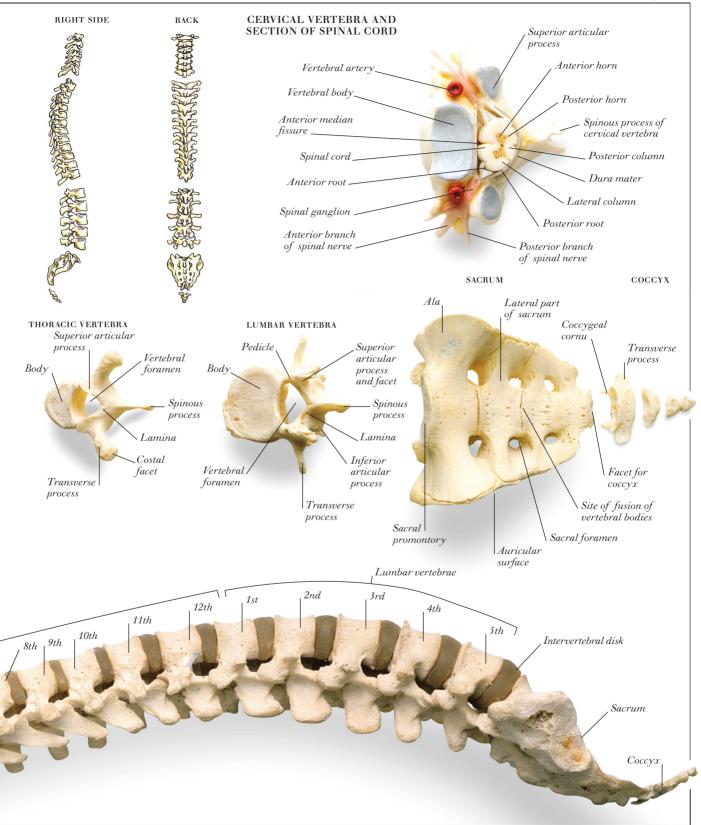
Spine

The spine (or vertebral column) has two main functions: it serves as a protective surrounding for the delicate spinal cord and forms the supporting back bone of the skeleton. The spine consists of 24 separate differently shaped bones (vertebrae) with a curved, triangular bone (the sacrum) at the bottom. The sacrum is made up of fused vertebrae; at its lower end is a small tail-like structure made up of tiny bones collectively called the coccyx. Between each pair of vertebrae is a disk of cartilage that cushions the bones during movement. The top two vertebrae differ in appearance from the others and work as a pair: the first, called the atlas, rotates around a stout vertical peg on the second, the axis. This arrangement allows the skull to move freely up and down, and from side to side.

SPINE DIVIDED INTO VERTEBRAL SECTIONS Cervical vertebrae Thoracic vertebrae Lumbar vertebrae Sacral vertebrae Coccygeal vertebrae

TYPES OF VERTEBRAE (VIEWED FROM ABOVE)

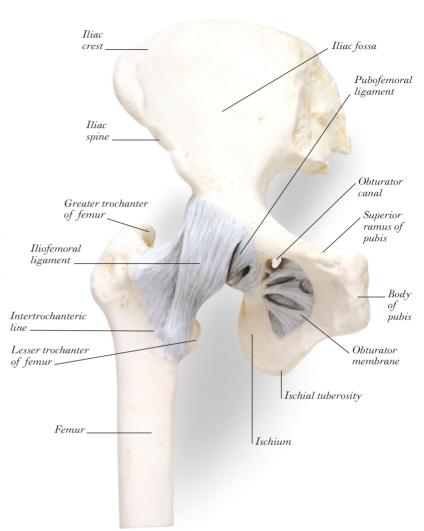




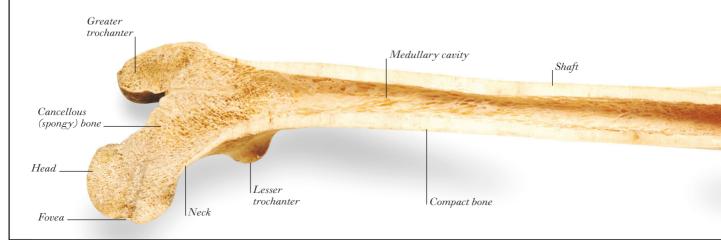
Bones and joints

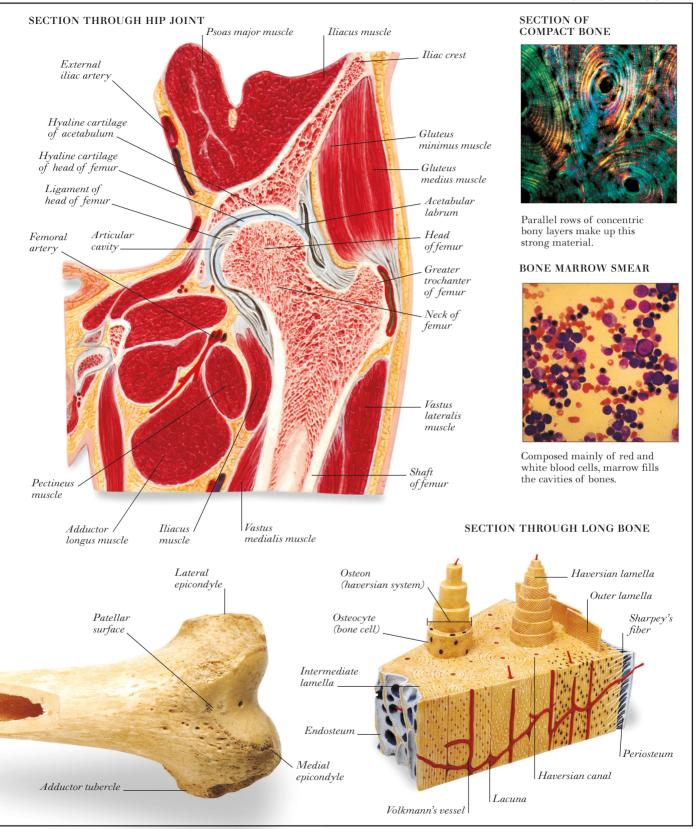
BONES FORM the body's hard, strong skeletal framework. Each bone has a hard, compact exterior surrounding a spongy, lighter interior. The long bones of the arms and legs, such as the femur (thigh bone), have a central cavity containing bone marrow. Bones are composed chiefly of calcium, phosphorus, and a fibrous substance known as collagen. Bones meet at joints, which are of several different types. For example, the hip is a ball-and-socket joint that allows the femur a wide range of movement, whereas finger joints are simple hinge joints that allow only bending and straightening. Joints are held in place by bands of tissue called ligaments. Movement of joints is facilitated by the smooth hyaline cartilage that covers the bone ends and by the synovial membrane that lines and lubricates the joint.

LIGAMENTS SURROUNDING HIP JOINT



SECTION THROUGH LEFT FEMUR

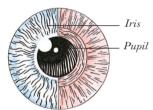




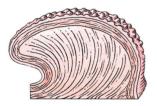
Muscles 1

THERE ARE THREE MAIN TYPES OF MUSCLE: skeletal muscle (also called voluntary muscle because it can be consciously controlled); smooth muscle (also called involuntary muscle because it is not under voluntary control); and the specialized muscle tissue of the heart. Humans have more than 600 skeletal muscles, which differ in size and shape according to the jobs they do. Skeletal muscles are attached either directly or indirectly (via tendons) to bones, and work in opposing pairs (one muscle in the pair contracts while the other relaxes) to produce body movements as diverse as walking, threading a needle, and an array of facial expressions. Smooth muscles occur in the walls of internal body organs and perform actions such as forcing food through the intestines, contracting the uterus (womb) in childbirth, and pumping blood through the blood vessels.

SOME OTHER MUSCLES IN THE BODY



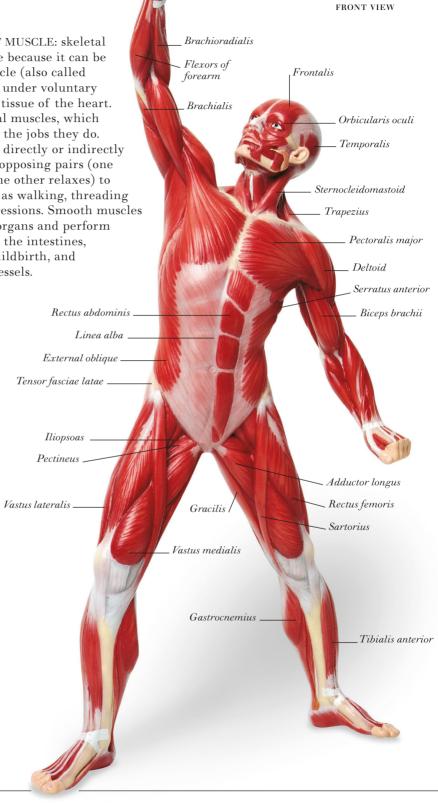
IRIS
The muscle fibers contract and dilate (expand) to alter pupil size.



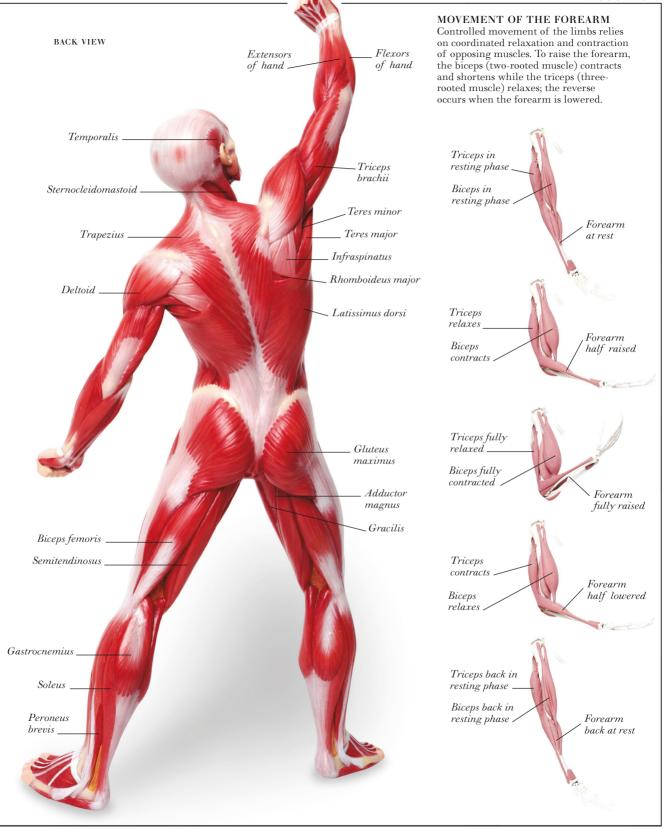
TONGUE Interlacing layers of muscle allow great mobility.



ILEUM Opposing muscle layers transport semidigested food.



SUPERFICIAL SKELETAL MUSCLES



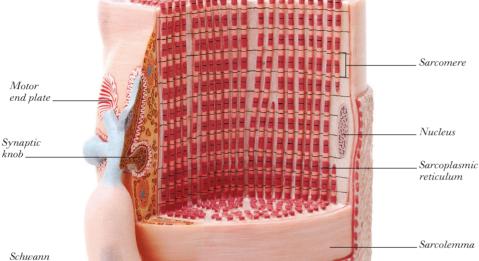
Muscles 2 SKELETAL MUSCLE FIBER

MUSCLES OF FACIAL EXPRESSION A single expression is the result of movement of many muscles; the main muscles of expression are shown in action below.

Endomysium



FRONTALIS



Myofibril



CORRUGATOR SUPERCILII

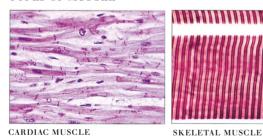


ORBICULARIS ORIS

TYPES OF MUSCLE

neuron Node of Ranvier

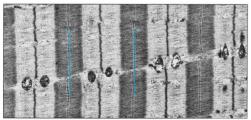
cell -Motor

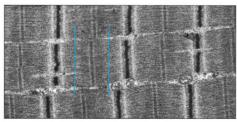




ZYGOMATICUS MAJOR

CONTRACTION OF SKELETAL MUSCLE



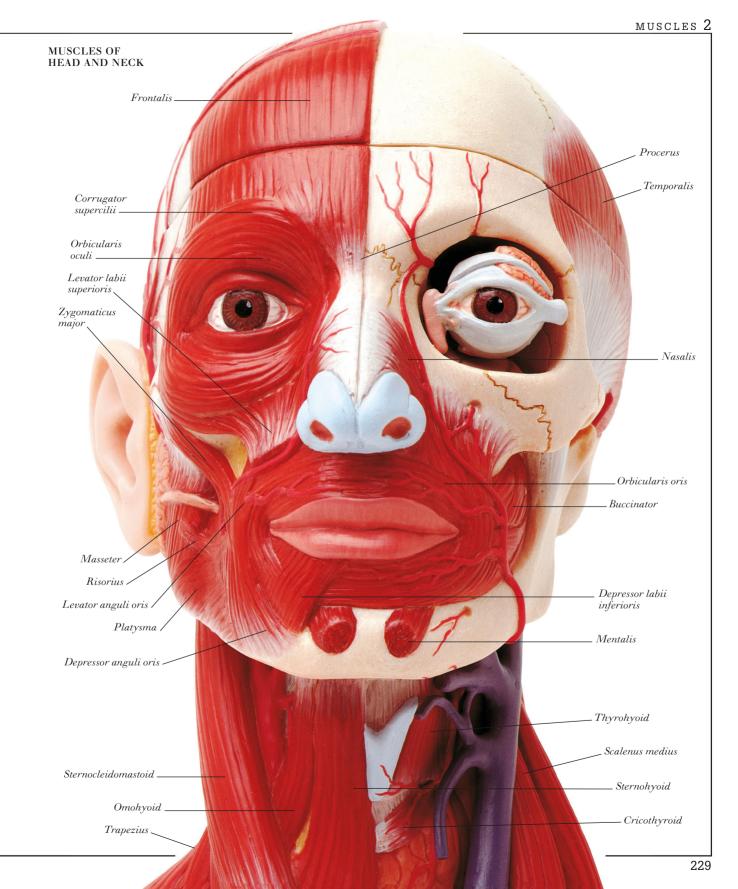


SMOOTH MUSCLE

DEPRESSOR ANGULI ORIS

CONTRACTED STATE

RELAXED STATE



Hands



THE HUMAN HAND is an extremely versatile tool, capable of delicate manipulation as well as powerful gripping actions. The arrangement of its 27 small bones, moved by 37 skeletal muscles that are connected to the bones by tendons, allows a wide range of movements. Our ability to bring the tips of our thumbs and fingers

Middle

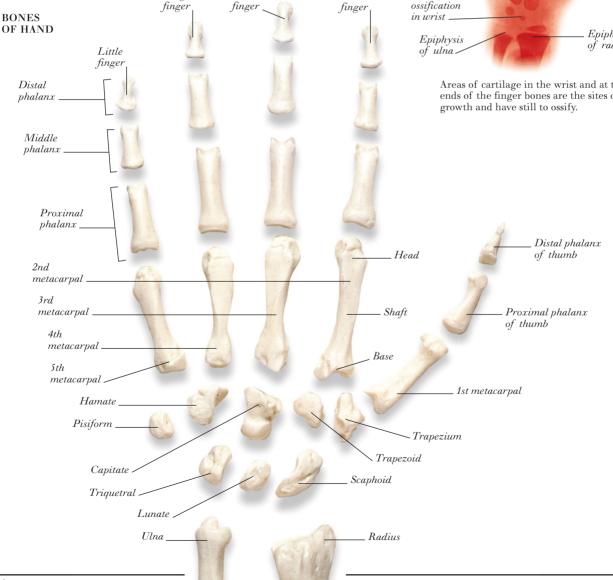
together, combined with the extraordinary sensitivity of our fingertips due to their rich supply of nerve endings, makes our hands uniquely dextrous.

Ring

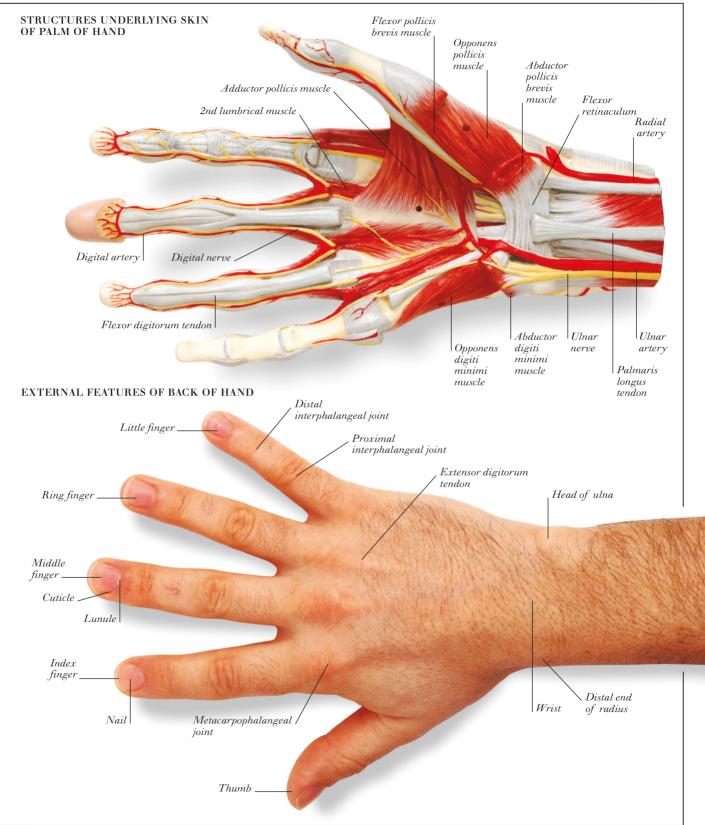
Area of ossification in phalanx Area of ossification in metacarpal Area of ossification in wrist. Epiphysis Epiphysis of radius of ulna. Areas of cartilage in the wrist and at the ends of the finger bones are the sites of growth and have still to ossify.

X-RAY OF LEFT HAND

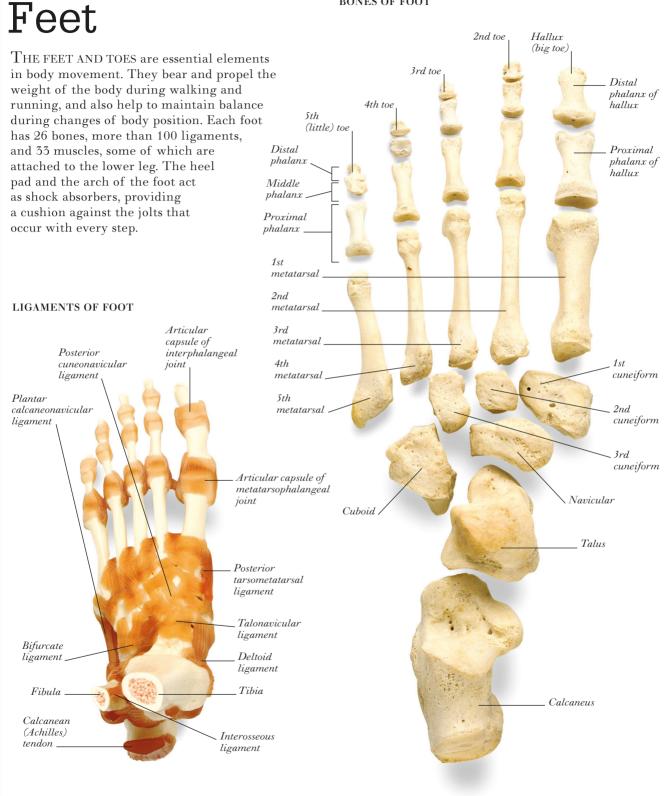
OF A YOUNG CHILD

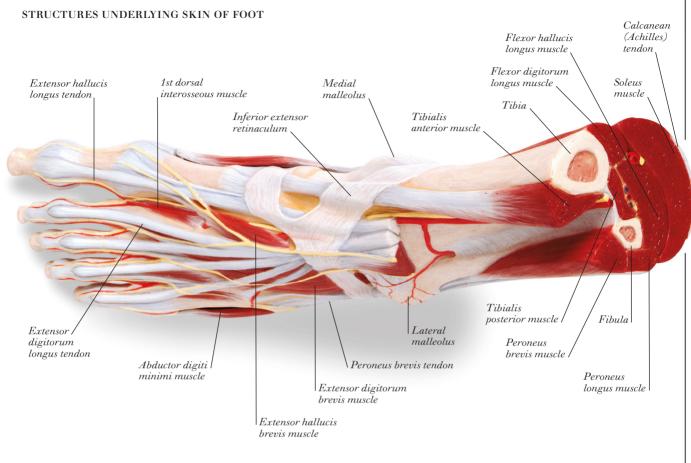


Index

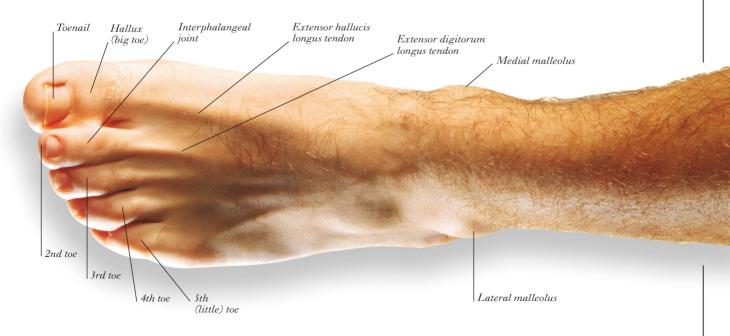


BONES OF FOOT





EXTERNAL FEATURES OF FOOT



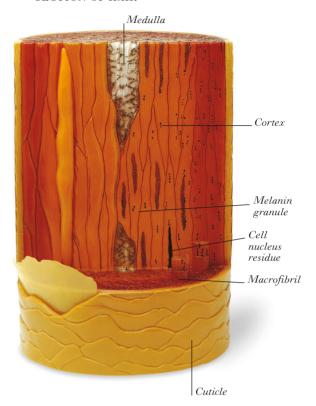
Skin and hair



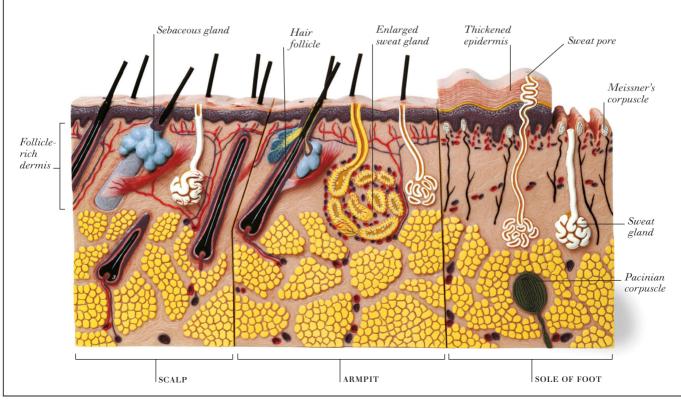
SKIN IS THE BODY'S LARGEST ORGAN, a waterproof barrier that protects the internal organs against infection, injury, and harmful sun rays. The skin is also an important sensory organ and helps to control body

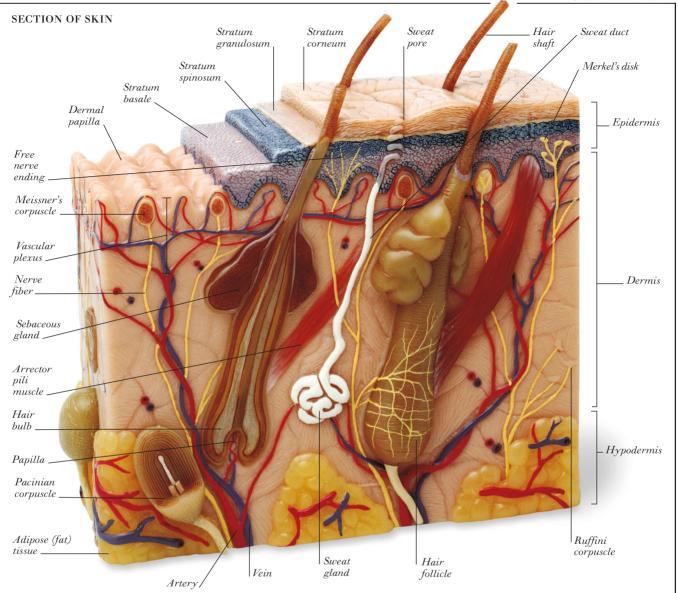
temperature. The outer layer of the skin, known as the epidermis, is coated with keratin, a tough, horny protein that is also the chief constituent of hair and nails. Dead cells are shed from the skin's surface and are replaced by new cells from the base of the epidermis, the region that also produces the skin pigment, melanin. The dermis contains most of the skin's living structures, and includes nerve endings, blood vessels, elastic fibers, sweat glands that cool the skin, and sebaceous glands that produce oil to keep the skin supple. Beneath the dermis lies the subcutaneous tissue (hypodermis), which is rich in fat and blood vessels. Hair shafts grow from hair follicles situated in the dermis and subcutaneous tissue. Hair grows on every part of the skin apart from the palms of the hands and soles of the feet.

SECTION OF HAIR



SECTIONS OF DIFFERENT TYPES OF SKIN





PHOTOMICROGRAPHS OF SKIN AND HAIR



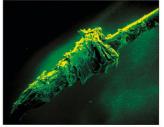
SECTION OF SKIN
The flaky cells at the skin's surface are shed continuously.



SWEAT PORE
This allows loss of fluid as part
of temperature control.



SKIN HAIR Two hairs pushing through the outer layer of skin.

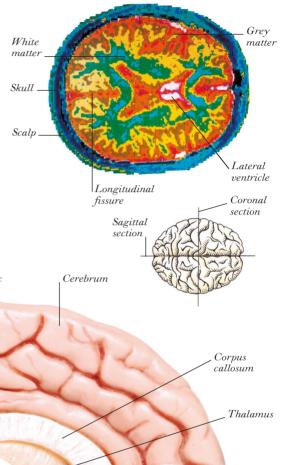


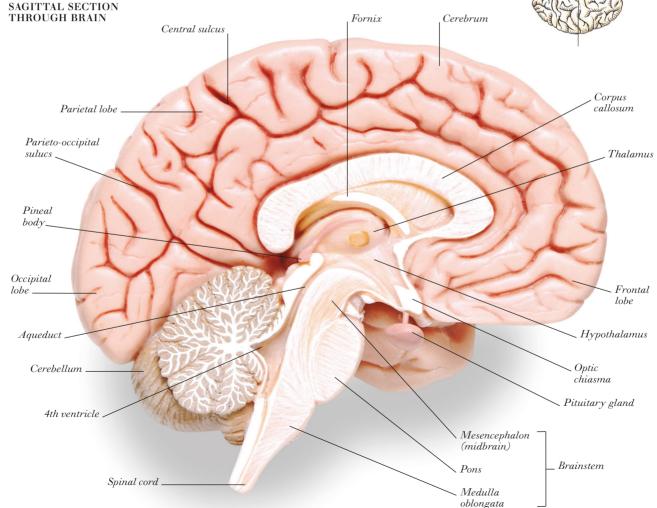
HEAD HAIR
The root and part of the shaft of a hair from the scalp.

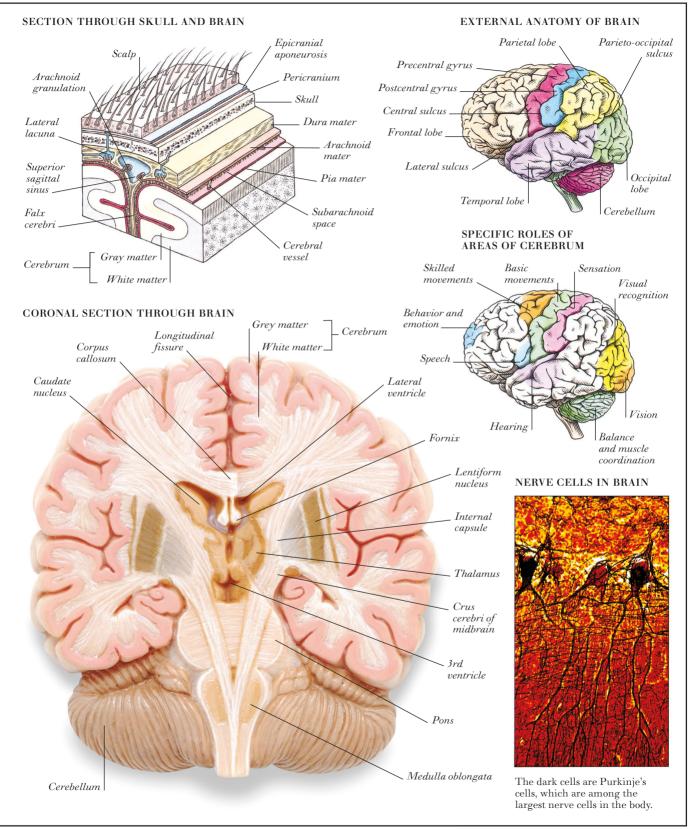
Brain

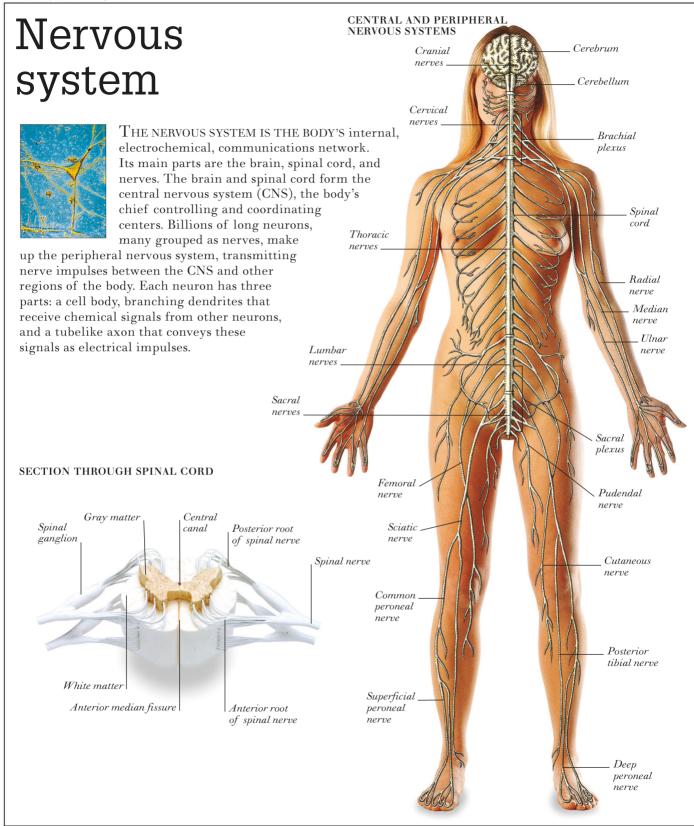
The Brain is the major organ of the central nervous system and the control center for all the body's voluntary and involuntary activities. It is also responsible for the complexities of thought, memory, emotion, and language. In adults, this complex organ is a mere 3 lb (1.4 kg) in weight, containing over 10 billion nerve cells. Three distinct regions can easily be seen—the brainstem, the cerebellum, and the large cerebrum. The brainstem controls vital body functions, such as breathing and digestion. The cerebellum's main functions are the maintenance of posture and the coordination of body movements. The cerebrum, which consists of the right and left cerebral hemispheres joined by the corpus callosum, is the site of most conscious and intelligent activities.

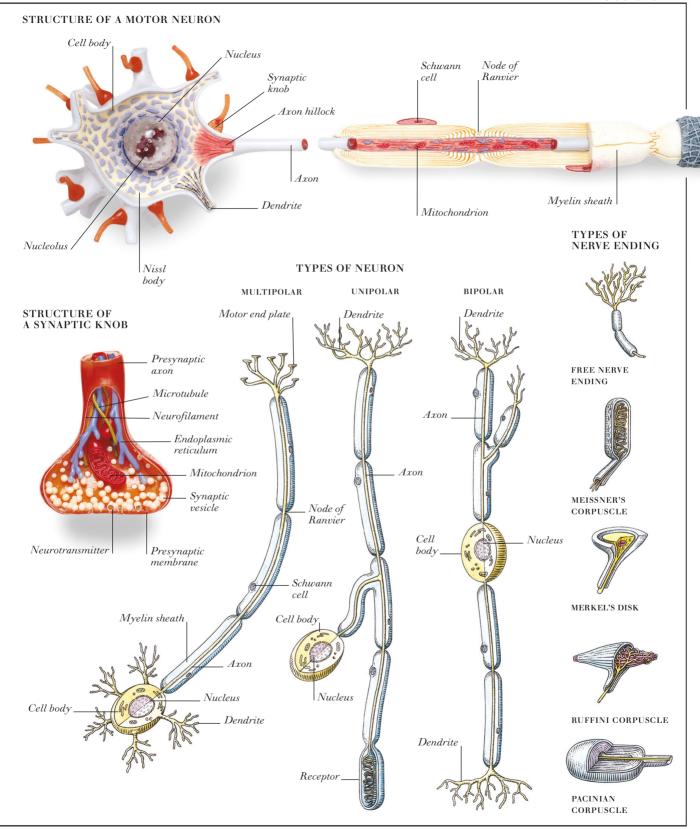
MRI SCAN OF TRANSVERSE SECTION THROUGH BRAIN



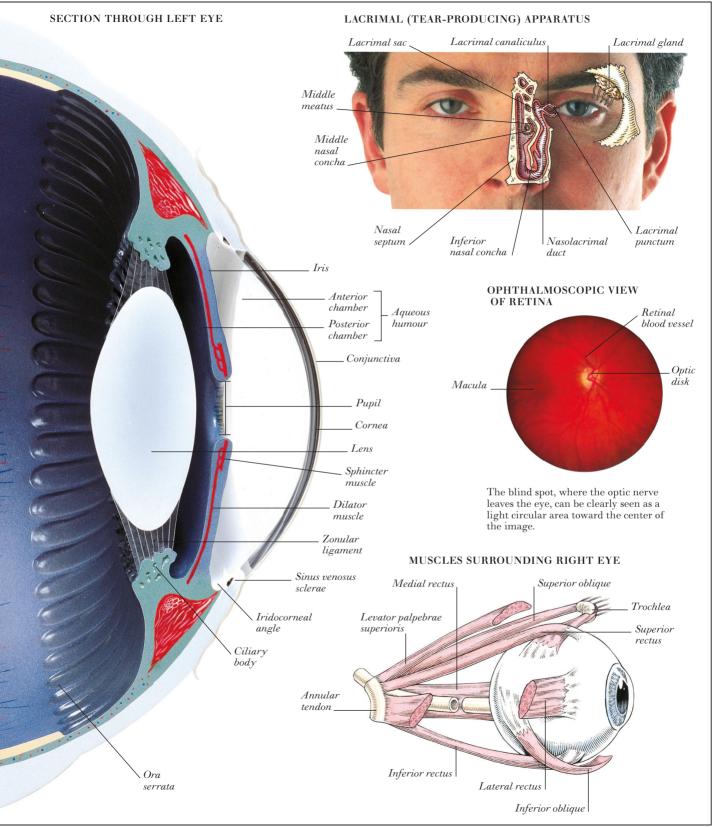








Medial rectus muscle



STRUCTURE OF EAR

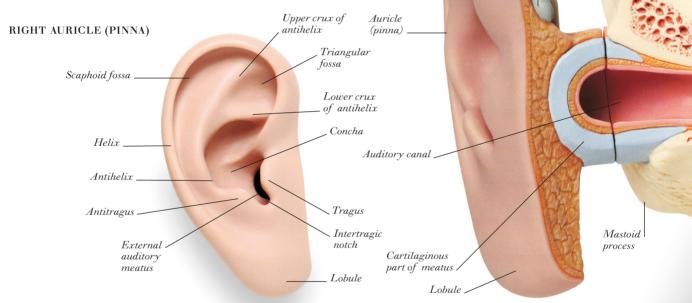
Cartilage

of auricle

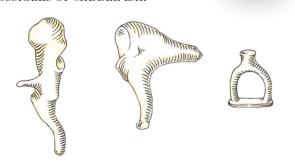
Temporal bone

Ear

The EAR IS THE ORGAN OF HEARING AND BALANCE. The outer ear consists of a flap called the auricle or pinna and the auditory canal. The main functional parts-the middle and inner ears-are enclosed within the skull. The middle ear consists of three tiny bones, known as auditory ossicles, and the eustachian tube, which links the ear to the back of the nose. The inner ear consists of the spiral-shaped cochlea, and also the semicircular canals and the vestibule, which are the organs of balance. Sound waves entering the ear travel through the auditory canal to the tympanic membrane (eardrum), where they are converted to vibrations that are transmitted via the ossicles to the cochlea. Here, the vibrations are converted by millions of microscopic hairs into electrical nerve signals to be interpreted by the brain.



OSSICLES OF MIDDLE EAR

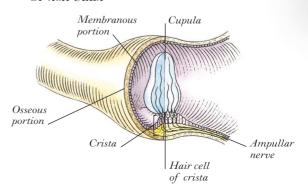


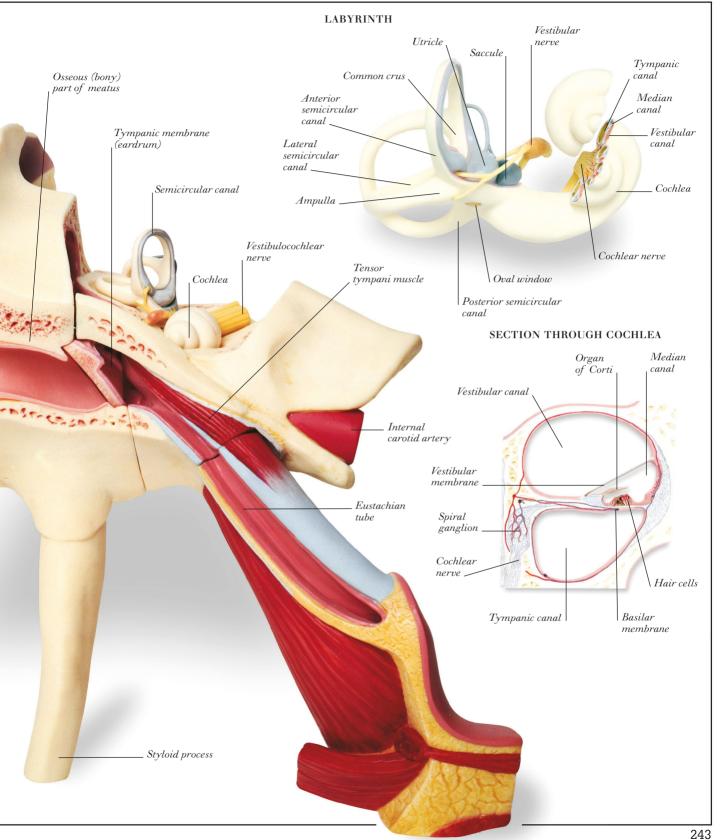
MALLEUS (HAMMER) INCUS (ANVIL)

STAPES (STIRRUP)

These three tiny bones connect to form a bridge between the tympanic membrane and the oval window. With a system of membranes they convey sound vibrations to the inner ear.

INTERNAL STRUCTURE OF AMPULLA

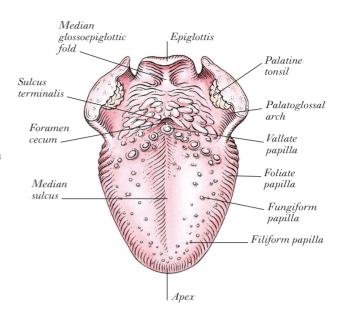




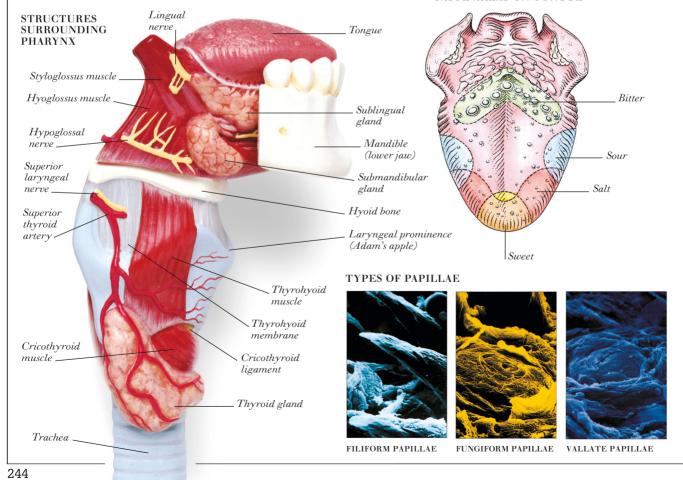
Nose, mouth, and throat

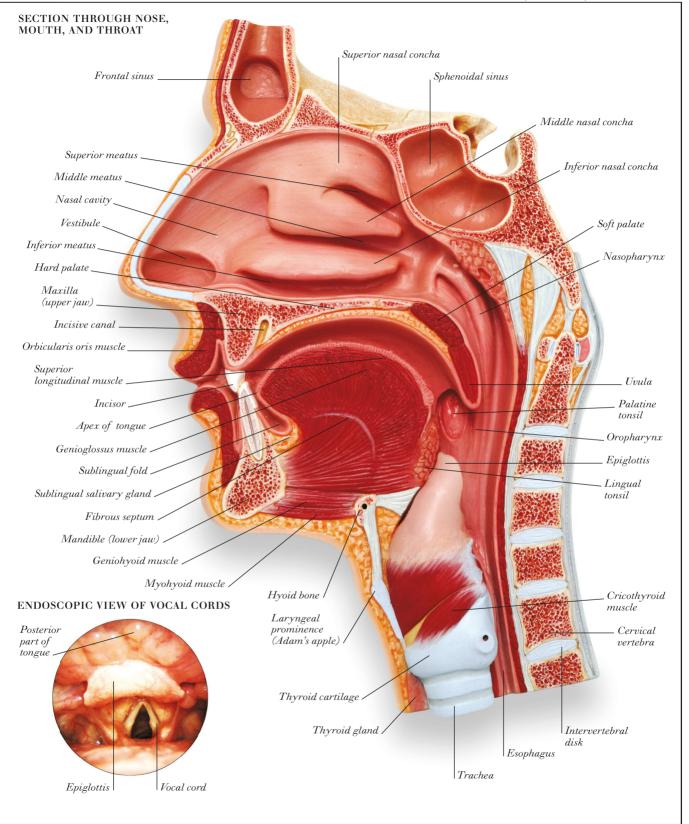
WITH EVERY BREATH, air passes through the nasal cavity down the pharynx (throat), larynx ("voice box"), and trachea (windpipe) to the lungs. The nasal cavity warms and moistens air, and the tiny layers in its lining protect the airway against damage by foreign bodies. During swallowing, the tongue moves up and back, the larynx rises, the epiglottis closes off the entrance to the trachea, and the soft palate separates the nasal cavity from the pharynx. Saliva, secreted from three pairs of salivary glands, lubricates food to make swallowing easier; it also begins the chemical breakdown of food, and helps to produce taste. The senses of taste and smell are closely linked. Both depend on the detection of dissolved molecules by sensory receptors in the olfactory nerve endings of the nose and in the taste buds of the tongue.

STRUCTURE OF TONGUE



TASTE AREAS ON TONGUE





DEVELOPMENT OF TEETH IN A FETUS

Teeth

The 20 primary teeth (also called deciduous or baby teeth) usually begin to erupt when a baby is about six months old. They start to be replaced by the permanent teeth when the child is about six years old. By the age of 20, most adults have a full set of 32 teeth although the third molars (commonly called wisdom teeth) may never erupt. While teeth help people to speak clearly and give shape to the face, their main function is the chewing of food. Incisors and canines shear and tear the food into pieces; premolars and molars crush and grind it further. Although tooth enamel is the hardest substance in the body, it tends to be eroded and destroyed by acid produced in the mouth during the breakdown of food.

Primary teeth in maxilla (upper jaw) Primary teeth in mandible (lower jaw)

FETAL JAWS

By the sixth week of embryonic development areas of thickening occur in each jaw; these areas give rise to tooth buds. By the time the fetus is six months old, enamel has formed on the tooth buds.

DEVELOPMENT OF JAW AND TEETH









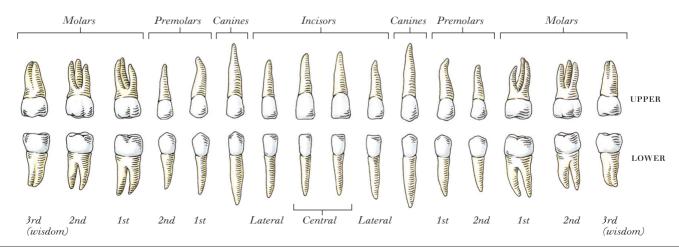
A NEWBORN BABY'S JAWS
The primary teeth can be seen
developing in the jaw bones;
they begin to erupt around the
age of six months.

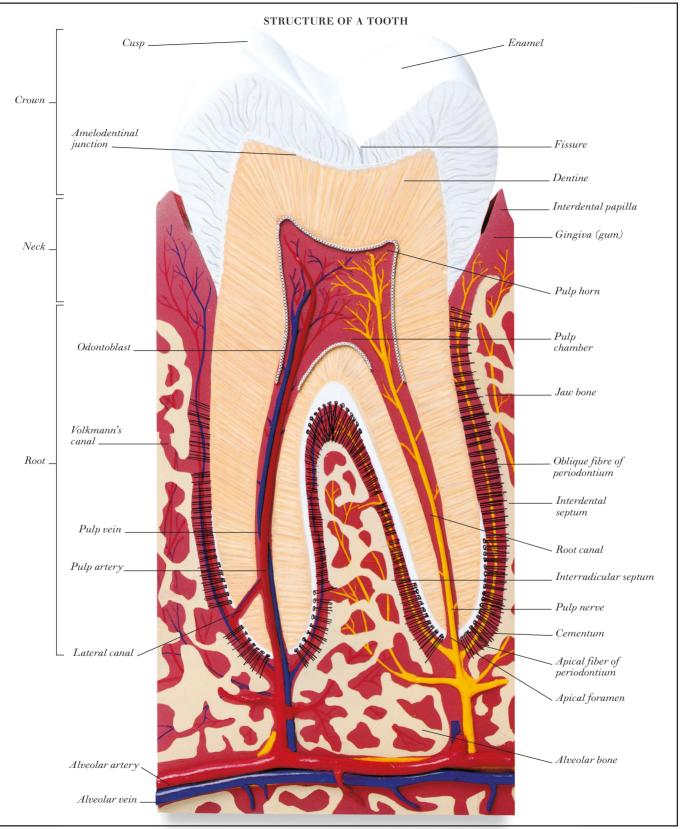
A FIVE-YEAR-OLD CHILD'S TEETH There is a full set of 20 erupted primary teeth; the permanent teeth can be seen developing in the upper and lower jaws.

A NINE-YEAR-OLD CHILD'S TEETH Most of the teeth are primary teeth but the permanent incisors and first molars have now emerged.

AN ADULT'S TEETH By the age of 20, the full set of 32 permanent teeth (including the wisdom teeth) should be in position.

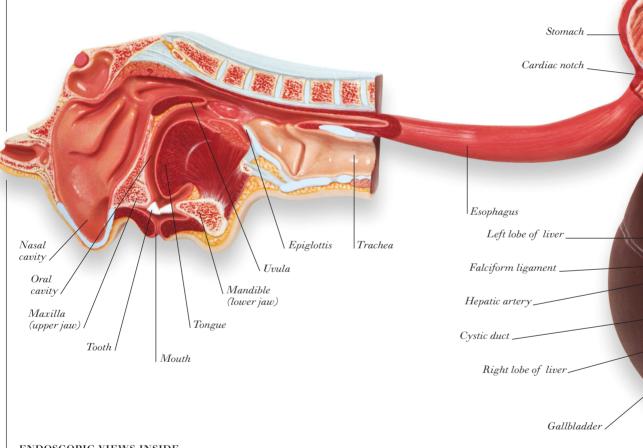
THE PERMANENT TEETH



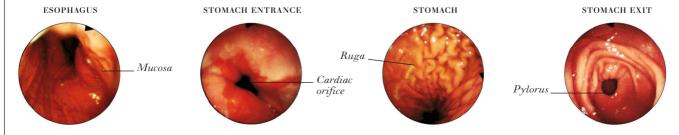


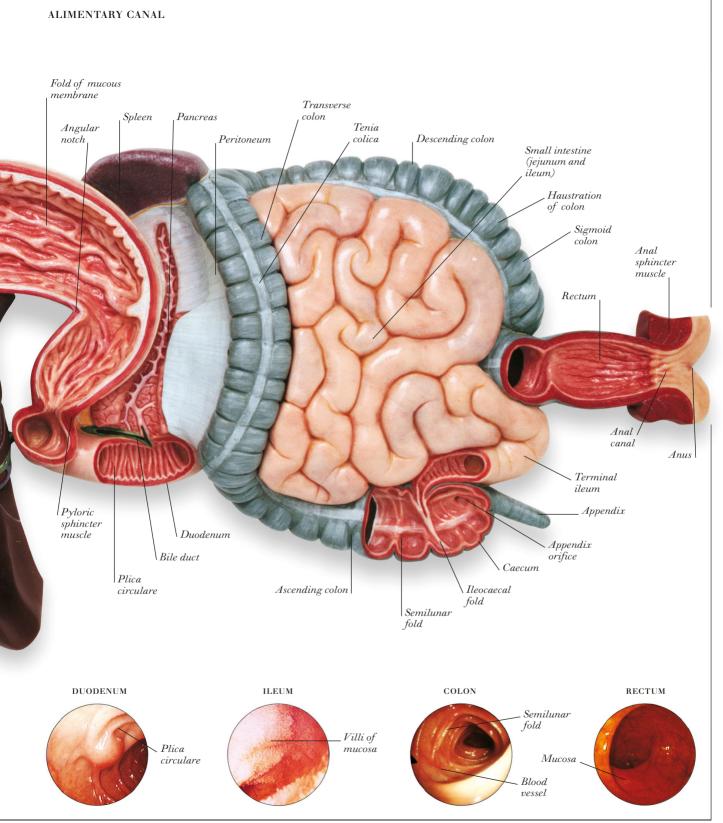
Digestive system

The digestive system breaks down food into particles so tiny that blood can take nourishment to all parts of the body. The system's main part is a 30 ft (9 m) tube from mouth to rectum; muscles in this alimentary canal force food along. Chewed food first travels through the esophagus to the stomach, which churns and liquidizes food before it passes through the duodenum, jejunum, and ileum—the three parts of the long, convoluted small intestine. Here, digestive juices from the gallbladder and pancreas break down food particles; many filter out into the blood through tiny fingerlike villi that line the small intestine's inner wall. Undigested food in the colon forms feces that leave the body through the anus.



ENDOSCOPIC VIEWS INSIDE ALIMENTARY CANAL





Heart

ARTERIES AND VEINS SURROUNDING HEART

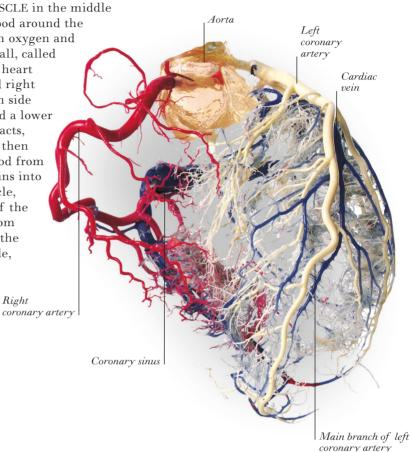
THE HEART IS A HOLLOW MUSCLE in the middle

of the chest that pumps blood around the body, supplying cells with oxygen and nutrients. A muscular wall, called the septum, divides the heart lengthwise into left and right sides. A valve divides each side

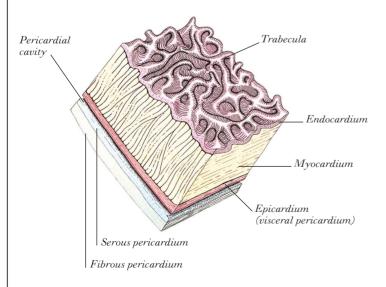
into two chambers: an upper atrium and a lower ventricle. When the heart muscle contracts, it squeezes blood through the atria and then through the ventricles. Oxygenated blood from the lungs flows from the pulmonary veins into the left atrium, through the left ventricle, and then out via the aorta to all parts of the body. Deoxygenated blood returning from the body flows from the vena cava into the right atrium, through the right ventricle, and then out via the pulmonary artery to the lungs for reoxygenation.

At rest the heart beats

At rest the heart beats between 60 and 80 times a minute; during exercise or at times of stress or excitement the rate may increase to 200 beats a minute.

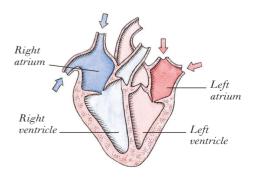


SECTION THROUGH HEART WALL

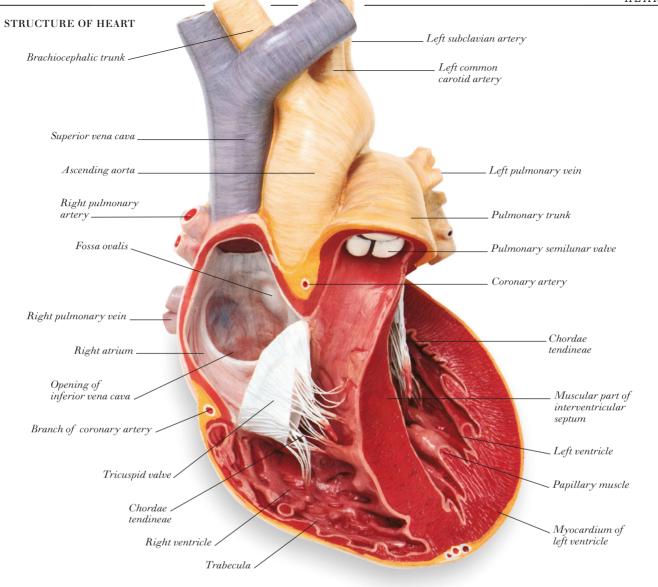


HEARTBEAT SEQUENCE

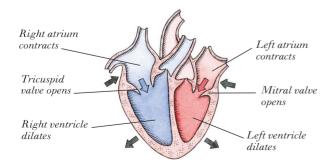
ATRIAL DIASTOLE



Deoxygenated blood enters the right atrium while the left atrium receives oxygenated blood.

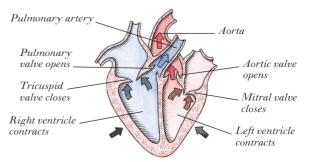


ATRIAL SYSTOLE (VENTRICULAR DIASTOLE)



Left and right atria contract, forcing blood into the relaxed ventricles.

VENTRICULAR SYSTOLE



Ventricles contract and force blood to the lungs for oxygenation and via the aorta to the rest of the body.

Circulatory system

THE CIRCULATORY SYSTEM consists of the heart and blood vessels, which together maintain a continuous flow of blood around the body. The heart pumps oxygen-rich blood from the lungs to all parts of the body through a network of tubes called arteries, and

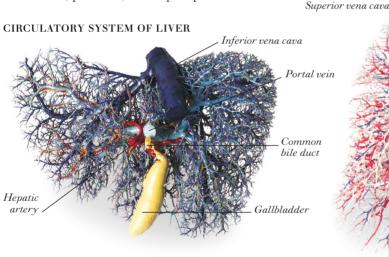
smaller branches called arterioles. Blood returns to the heart via small vessels called venules, which lead in turn into larger tubes called veins. Arterioles and venules are linked by a network of tiny vessels called capillaries, where the exchange of oxygen and carbon dioxide between blood and body cells takes place.

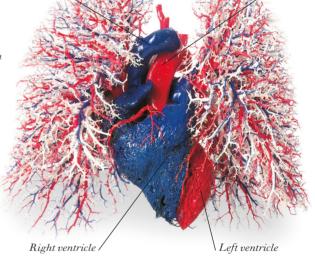
Blood has four main components: red blood cells, white blood cells, platelets, and liquid plasma.

Left internal carotid artery Basilar artery Posterior cerebral artery Left vertebral artery

ARTERIAL SYSTEM OF BRAIN

CIRCULATORY SYSTEM OF HEART AND LUNGS

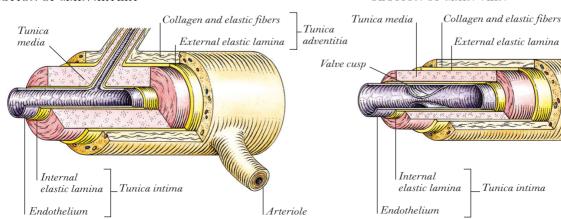




Tunica

adventitia

SECTION OF MAIN ARTERY



SECTION OF MAIN VEIN

PRINCIPAL ARTERIES AND VEINS OF CIRCULATORY SYSTEM Internal jugular vein Common Brachiocephalic vein carotid artery Subclavian vein Subclavian artery Axillary vein Arch of aorta Cephalic vein Axillary artery Superior vena cava Pulmonary artery Coronary artery Pulmonary vein Brachial artery. Basilic vein Gastric artery_ Hepatic portal vein Hepatic artery. Median cubital vein Splenic artery Superior . Inferior vena cava mesenteric artery Anterior median Radial _ veinartery GastroepiploicUlnarveinartery Palmar Palmar Digital archveinDigital artery Inferior mesenteric vein Common iliac artery Superior mesenteric vein Common iliac vein External iliac artery Internal iliac artery External iliac vein Femoral artery. Internal iliac vein Popliteal artery Peroneal artery Femoral vein Great saphenous vein Anterior tibial artery Short saphenous vein Posterior tibial artery Lateral plantar artery Dorsal metatarsal artery Dorsal venous arch Digital vein

TYPES OF BLOOD CELLS



RED BLOOD CELLS These cells are biconcave in shape to maximize their oxygen-carrying capacity.

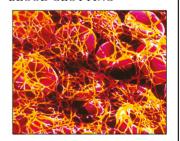


WHITE BLOOD CELLS Lymphocytes are the smallest white blood cells; they form antibodies against disease.



PLATELETS
Tiny cells that are activated whenever blood clotting or repair to vessels is necessary.

BLOOD CLOTTING



Filaments of fibrin enmesh red blood cells as part of the process of blood clotting.

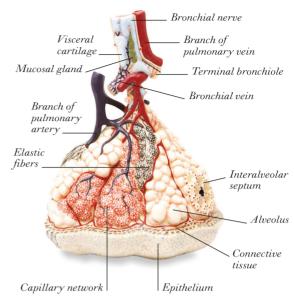
Respiratory system

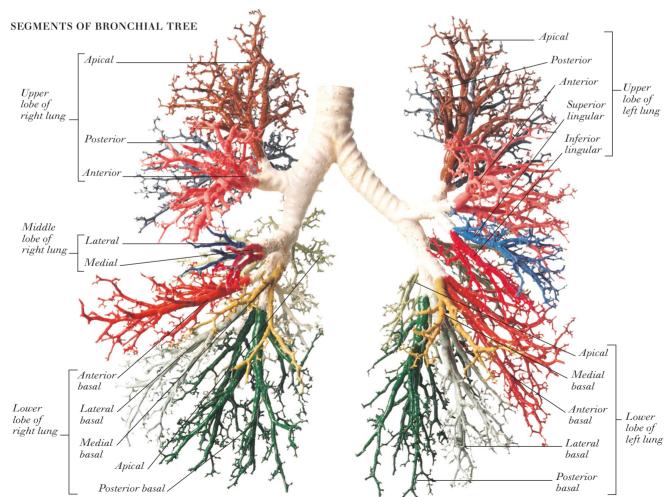


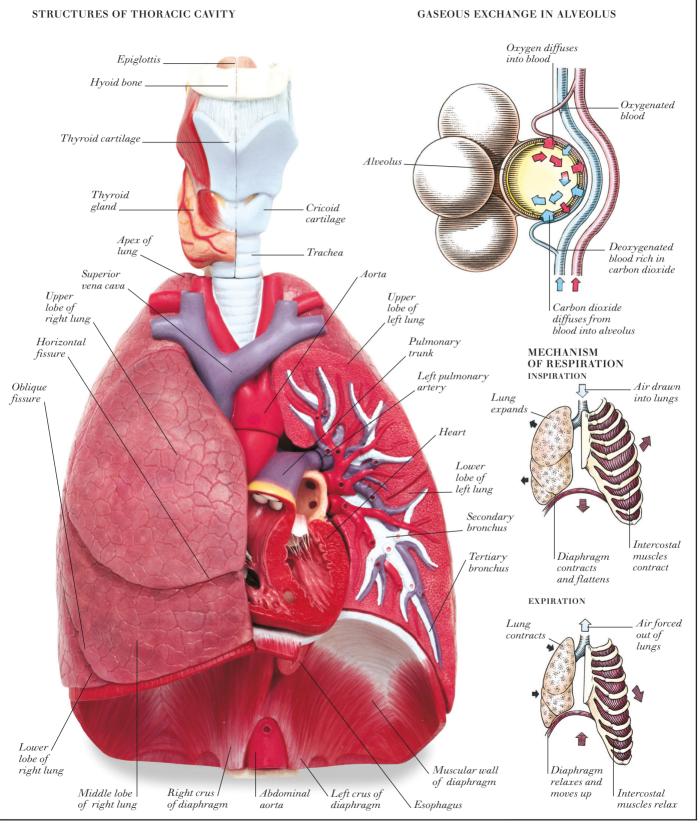
The respiratory system supplies the oxygen needed by body cells and carries off their carbon dioxide waste. Inhaled air passes via the trachea (windpipe) through two narrower tubes, the bronchi, to the lungs. Each lung comprises many fine, branching tubes called bronchioles that end in tiny clustered chambers called alveoli. Gases cross the thin

alveolar walls to and from a network of tiny blood vessels. Intercostal (rib) muscles and the muscular diaphragm below the lungs operate the lungs like bellows, drawing air in and forcing it out at regular intervals.

BRONCHIOLE AND ALVEOLI







Urinary system

ARTERIAL SYSTEM OF KIDNEYS

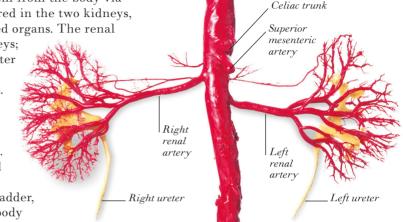
Aorta



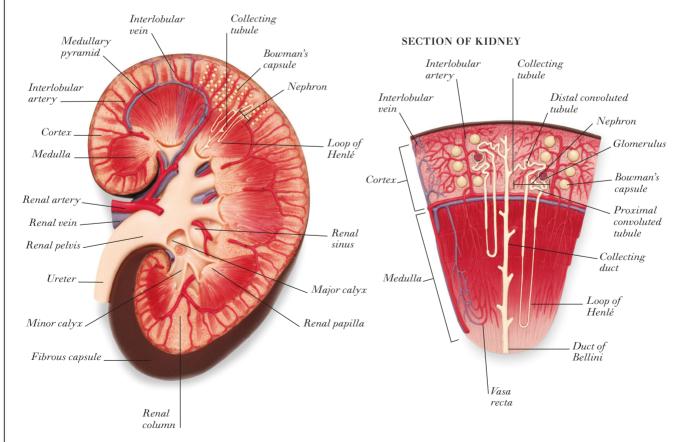
The urinary system filters waste products from the blood and removes them from the body via a system of tubes. Blood is filtered in the two kidneys, which are fist-sized, bean-shaped organs. The renal arteries carry blood to the kidneys;

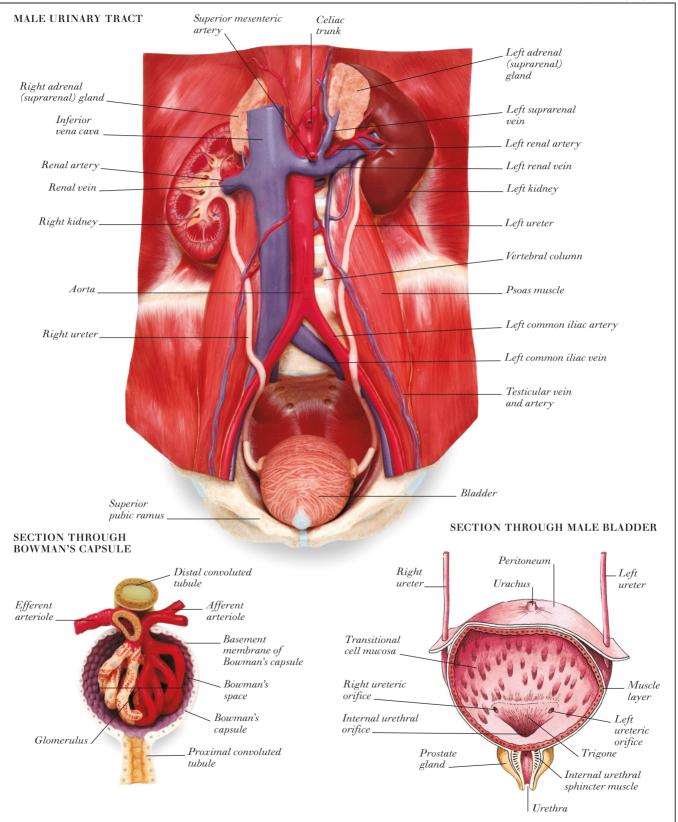
arteries carry blood to the kidneys; the renal veins remove blood after filtering. Each kidney contains

about one million tiny units called nephrons. Each nephron is made up of a tubule and a filtering unit called a glomerulus, which consists of a collection of tiny blood vessels surrounded by the hollow Bowman's capsule. The filtering process produces a watery fluid that leaves the kidney as urine. The urine is carried via two tubes called ureters to the bladder, where it is stored until its release from the body through another tube called the urethra.



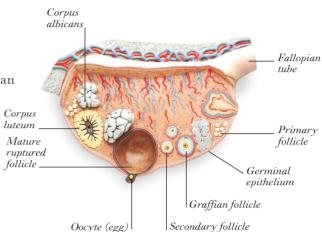
SECTION THROUGH LEFT KIDNEY



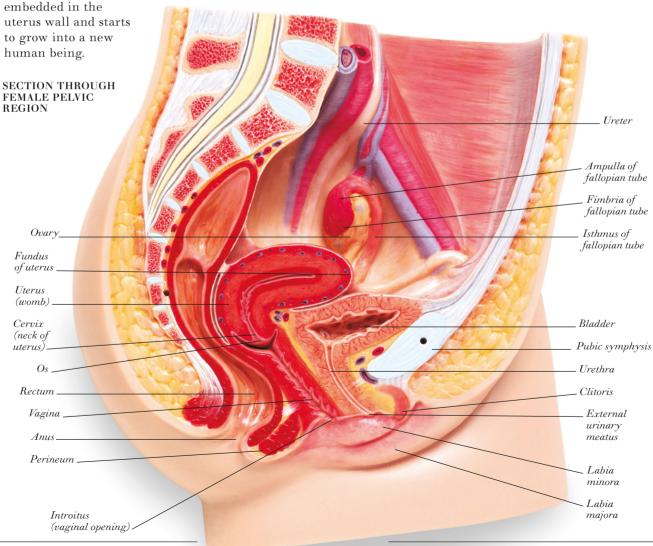


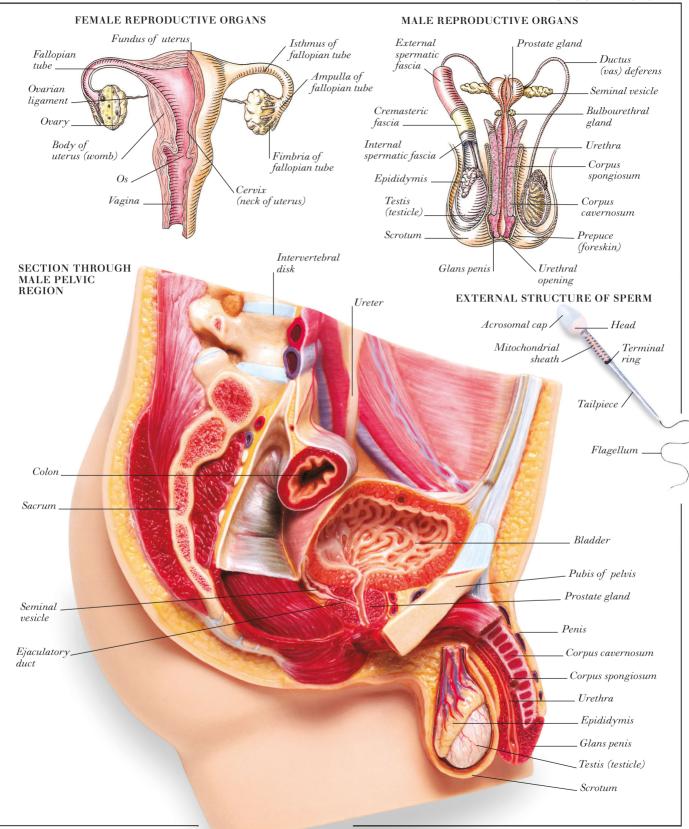
Reproductive system

SEX ORGANS LOCATED IN THE PELVIS create new human lives. Each month a ripe egg is released from one of the female's ovaries into a fallopian tube leading to the uterus (womb), a muscular pear-sized organ. A male produces minute tadpolelike sperm in two oval glands called testes. When the male is ready to release sperm into the female's vagina, many millions pass into his urethra and leave his body through the fleshy penis. The sperm travel up through the vagina into the uterus and fallopian tubes, and one sperm may enter and fertilize an egg. The fertilized egg becomes

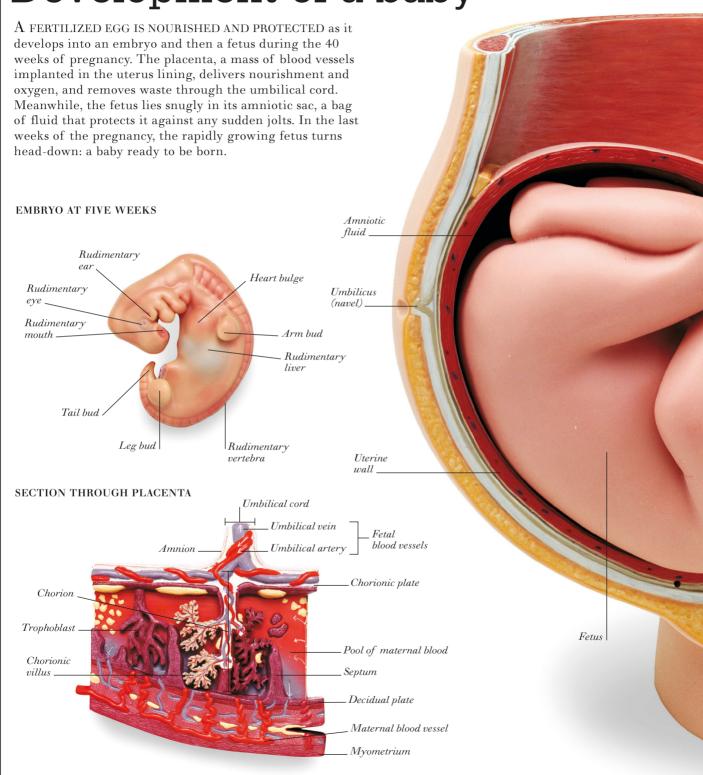


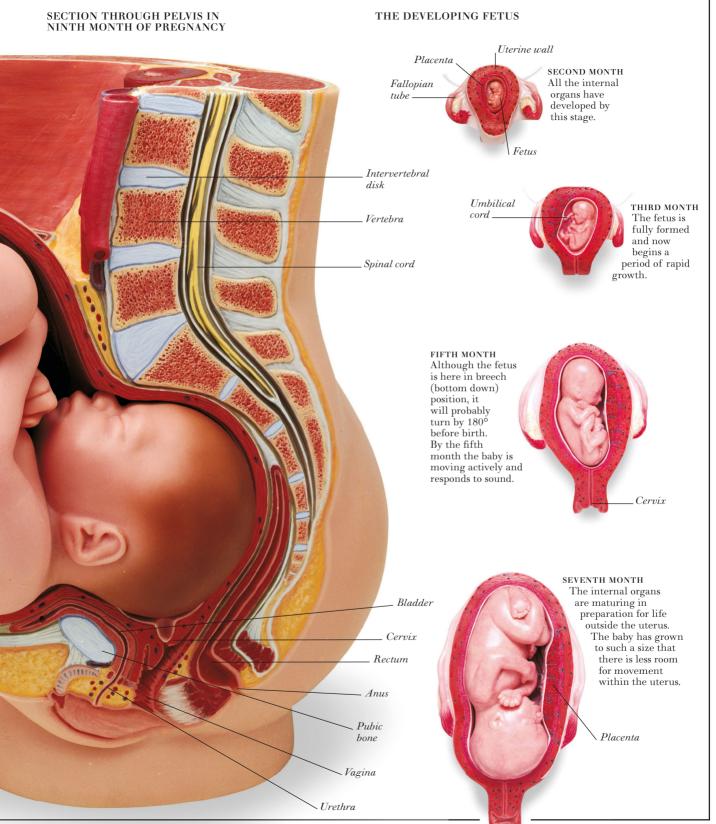
SECTION THROUGH OVARY





Development of a baby



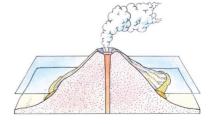






GEOLOGY, GEOGRAPHY, AND METEOROLOGY

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Mapping the Earth

THE EARTH'S SURFACE FEATURES can be represented in various ways, such as on maps and globes. The earliest know map of the whole world dates back to between 750–500 BCE. The first globe was constructed in the mid-2nd century BCE, about 100 years after ancient Greek astronomers established that the Earth was spherical. Advances in mathematics, science, and geography—combined with an increasing number of people exploring the world—have meant that Earth's surface features have been mapped with increasing accuracy throughout history. In modern times, advances in technology have revolutionized the mapping process. In 1972, NASA launched the first civilian remote-sensing vehicle

into Earth's orbit, which allowed the Earth to be mapped by satellite for the first time. Today, the surface of the Earth is surveyed every day by thousands of satellites, which send mappable data back to Earth to be analyzed and used by a range of people, from cartographers to scientists. The ability to use satellites has substantially sped up data collection—areas that would have once taken months or even years to survey can now be mapped within minutes. However, even with these advances in map-making, globes remain a more accurate way to represent the

Earth's surface features. This is because only a globe can correctly represent areas, shapes, sizes, and directions, as there is always distortion when a spherical surface like the Earth's is projected on to the flat surface of a map. A map projection is therefore always a compromise: it shows some features accurately but distorts others. Even satellite mapping does not produce completely accurate maps, although they can show physical features

EXAMPLES OF MAP PROJECTIONS





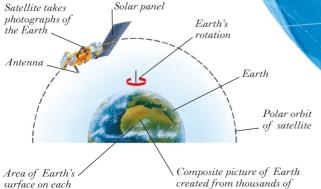
CYLINDRICAL PROJECTION

CYLINDRICAL-PROJECTION MAP



SATELLITE MAPPING OF THE EARTH

with great clarity.



separate images

Earth's rotation

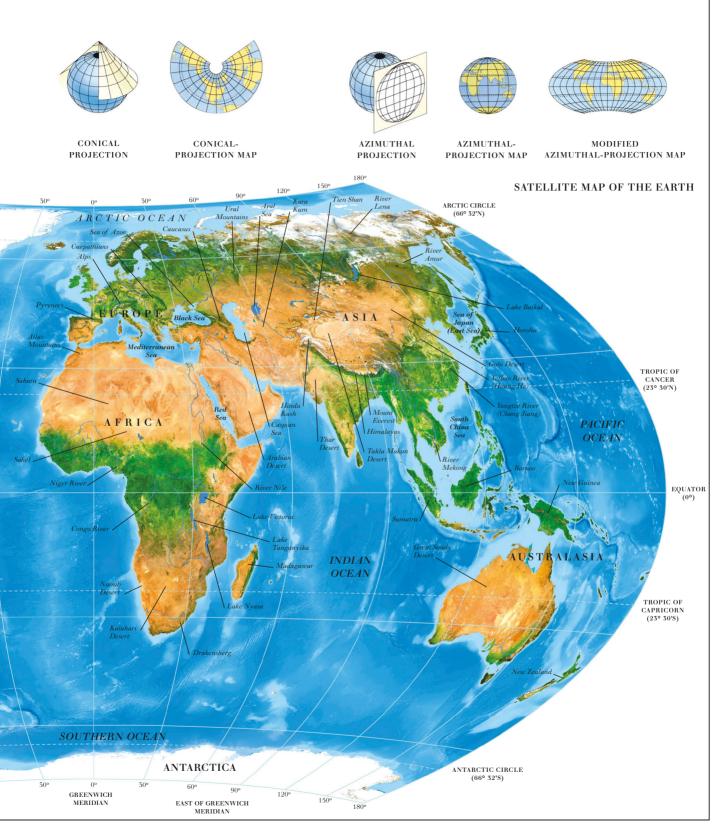
Earth

Polar orbit of satellite

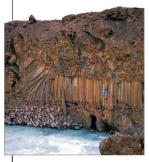
PACIFIC

150° WEST OF GREENWICH MERIDIAN

photograph



The rock cycle



HEXAGONAL BASALT COLUMNS, ICELAND

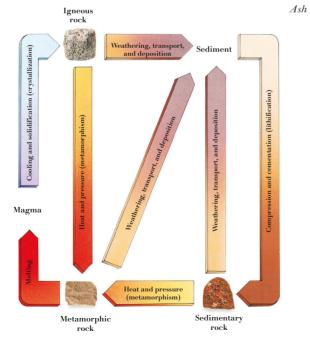
THE ROCK CYCLE IS A CONTINUOUS PROCESS through which old rocks are transformed into new ones. Rocks can be divided into three main groups: igneous, sedimentary, and metamorphic. Igneous rocks are formed when magma (molten rock) from the Earth's interior cools and solidifies (see pp. 274-275). Sedimentary rocks are formed when sediment (rock particles, for example) becomes compressed and cemented together in a process known as lithification (see pp. 276-277). Metamorphic rocks are formed when igneous, sedimentary, or other metamorphic rocks are changed by heat or pressure (see pp. 274-275). Rocks are added to the Earth's surface by crustal movements and volcanic activity. Once exposed on the surface, the rocks are broken down into rock particles by weathering (see pp. 282-283). The particles are then transported by glaciers, rivers, and wind, and deposited as sediment

of this sediment undergoes lithification and forms sedimentary rock. This rock may be thrust back to the surface by crustal movements or forced deeper into the Earth's interior, where heat and pressure transform it into metamorphic rock. The metamorphic rock in turn may be pushed up to the surface or may be melted to form magma. Eventually, the magma cools and solidifies—

Main below or on the surface—forming igneous rock. When the sedimentary, igneous, and metamorphic rocks are exposed once more on the Earth's surface, the conduit cycle begins again.

Lava

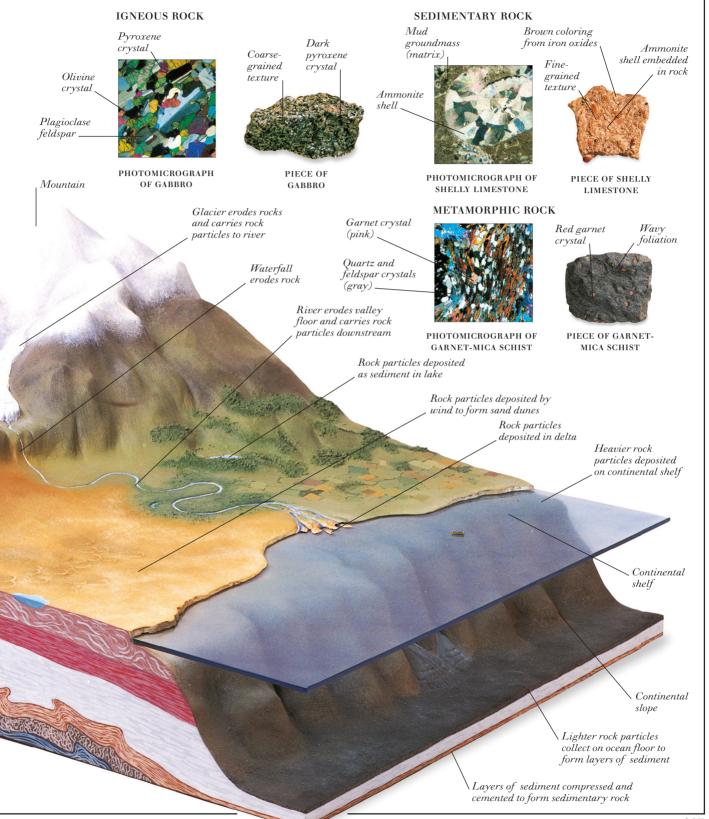
THE ROCK CYCLE



which solidifies to form igneous rock LavaVent flow Main conduit Secondary Rock surrounding magma changed by heat to form metamorphic rock Sedimentary rock crushed and folded to Intense heat of rising form metamorphic rock

magma melts some of the surrounding rock STAGES IN THE ROCK CYCLE

Magma extruded as lava,



Minerals

A MINERAL IS A NATURALLY OCCURRING SUBSTANCE that has a characteristic chemical composition and specific physical properties, such as habit and streak (see pp. 270-271). A rock, by comparison, is an aggregate of minerals and need not have a specific chemical composition. Minerals are made up of elements (substances that cannot be broken down chemically into simpler substances), each of which can be represented by a chemical symbol. Minerals can be divided into two main groups: native elements and compounds. Native elements are made up of a pure element. Examples include gold (chemical symbol Au), silver (Ag), copper (Cu), and carbon (C); carbon occurs as a native element in two forms, diamond and graphite. Compounds are combinations of two or more elements. For example, sulfides are compounds of sulfur (S) and one or more other elements, such as lead (Pb) in the mineral galena, or antimony (Sb)

in the mineral stibnite. groundmass Dendritic COPPER (matrix) (branching) (Cu) SULFIDES White goldHexagonal diamond graphite Kimberlite crystal groundmass (matrix) Ouartz vein GOLD DIAMOND GRAPHITE (Au) (C) (C) Rounded bauxite Cubic OXIDES/HYDROXIDES grains in groundmass galena (matrix) crystal Milky quartz groundmass Mass of specular (matrix) hematite Smoky crystals GALENA quartz (PbS) crystal SMOKY OUARTZ Prismatic SPECULAR HEMATITE stibnite (SiO_o) (Fe₂O₅)crystal BAUXITE (FeO(OH) and Al₂O₅,2H₂O) Ouartz Specular groundmass Kidney ore crystals of (matrix) STIBNITE hematite hematite (Sb_0S_3) **Ouartz** Perfect octahedral crystal pyrites crysta Parallel bands of onyxPYRITES ONYX KIDNEY ORE HEMATITE (FeS₂) (SiO_o) (Fe₂O₂)

NATIVE ELEMENTS

Limonite

Dendritic (branching) copper____



Mineral features

CLEAVAGE Cleavage in one direction

Cleavage in three directions. forming a block cube

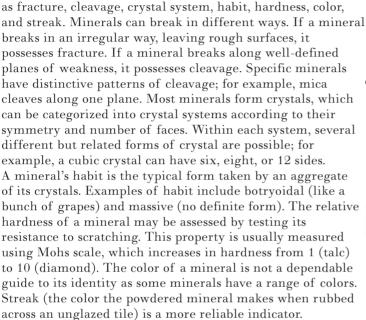
CLEAVAGE ALONG ONE PLANE

Horizontal cleavage Vertical cleavage

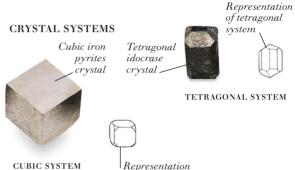


CLEAVAGE ALONG TWO PLANES

CLEAVAGE ALONG FOUR PLANES



MINERALS CAN BE IDENTIFIED BY STUDYING features such

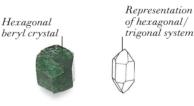


of cubic system

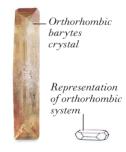




Nickel-iron with hackly (jagged) fracture



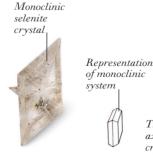
HEXAGONAL/TRIGONAL SYSTEM

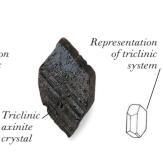


ORTHORHOMBIC SYSTEM

CONCHOIDAL FRACTURE

HACKLY FRACTURE Orpiment with uneven fracture Garnierite with splintery fracture





UNEVEN FRACTURE

SPLINTERY FRACTURE

MONOCLINIC SYSTEM

TRICLINIC SYSTEM



Volcanoes

 ${
m Vol}$ CANOES ARE VENTS OR FISSURES in the Earth's crust through which magma (molten rock that originates from deep beneath the crust) is forced on to the surface as lava. They occur most commonly along the boundaries of crustal plates; most volcanoes

lie in a belt called the "Ring of Fire," which runs along the edge of the Pacific Ocean. Volcanoes can be classified according to the violence and frequency of their eruptions.



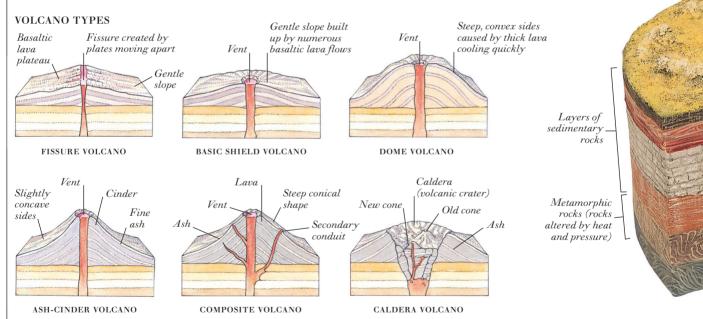
HORLI GEYSER. NEW ZEALAND

Nonexplosive volcanic eruptions generally occur where crustal plates pull apart. These eruptions produce runny basaltic lava that spreads quickly over a wide area to form relatively flat cones. The most violent eruptions take place where plates collide. Such eruptions produce thick rhyolitic lava and may also blast out clouds of dust and pyroclasts (lava fragments). The lava does not flow far before cooling and therefore builds up steep-sided, conical volcanoes. Some volcanoes produce lava and ash eruptions, which build up composite volcanic cones. Volcanoes that erupt frequently are described as active; those that erupt rarely are termed dormant; and those that have stopped erupting altogether are termed extinct. As well as the volcanoes themselves, other features associated with volcanic regions include geysers, hot mineral springs, solfataras, fumaroles, and bubbling mud pools.

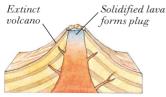


Folded, ropelike surface_

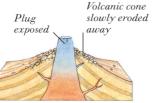
РАНОЕНОЕ (ROPY LAVA)



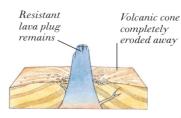




PLUG FORMATION



INITIAL EROSION AROUND PLUG

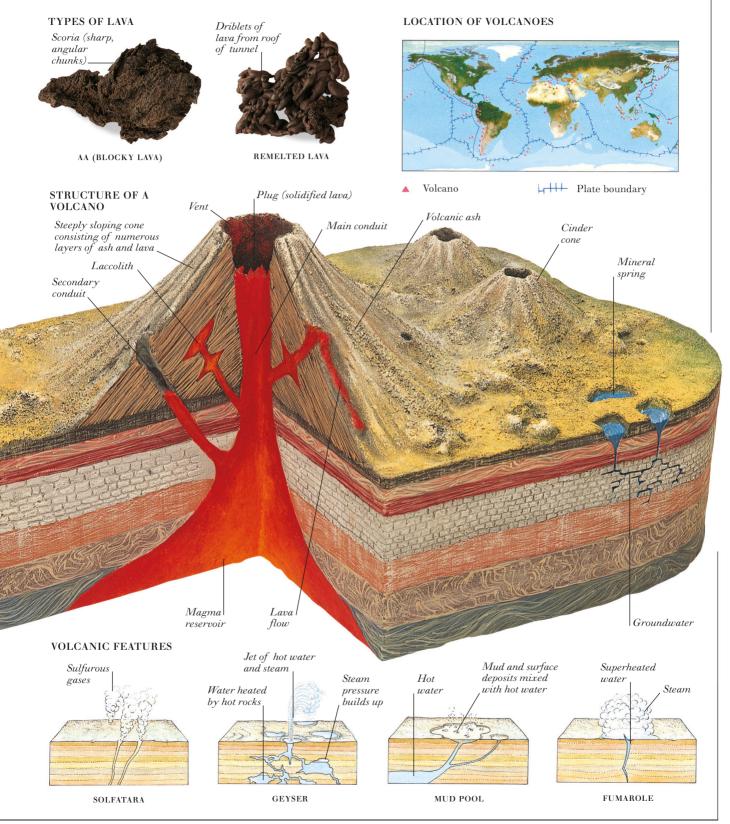


COMPLETE DENUDATION OF PLUG

LAPILLI (LAVA FRAGMENTS)



piece of solidified lava



Igneous and metamorphic rocks

IGNEOUS ROCKS ARE FORMED WHEN MAGMA (molten rock that originates from deep beneath the Earth's crust) cools and solidifies. There are two main types of igneous rock: intrusive and extrusive. Intrusive rocks are formed deep underground where magma is forced into cracks or between rock layers to form structures

such as sills, dikes, and batholiths. The magma cools slowly to form coarse-grained rocks such as gabbro and pegmatite.

Extrusive rocks are formed above the Earth's surface from lava (magma that has been ejected in a volcanic eruption). The molten lava cools quickly, producing fine-grained rocks such as rhyolite and basalt. Metamorphic rocks are those that have been altered by intense heat (contact metamorphism) or extreme pressure (regional metamorphism). Contact metamorphism occurs when rocks are changed by heat from, for example, an igneous intrusion or lava flow. Regional metamorphism occurs when rock is crushed in the middle of a folding mountain range. Metamorphic rocks can be formed from igneous rocks, sedimentary rocks, or even from other metamorphic rocks.

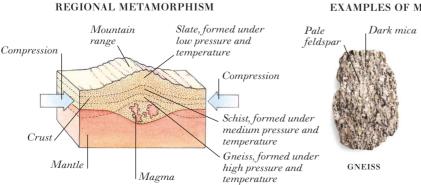
CONTACT METAMORPHISM

Metamorphic aureole (region where contact metamorphism occurs)

Hot igneous intrusion

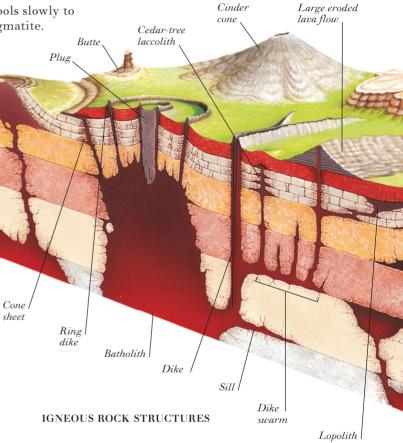
Marble Slate (metamorphosed (metamorphosed limestone) shale)

EXAMPLES OF METAMORPHIC ROCKS



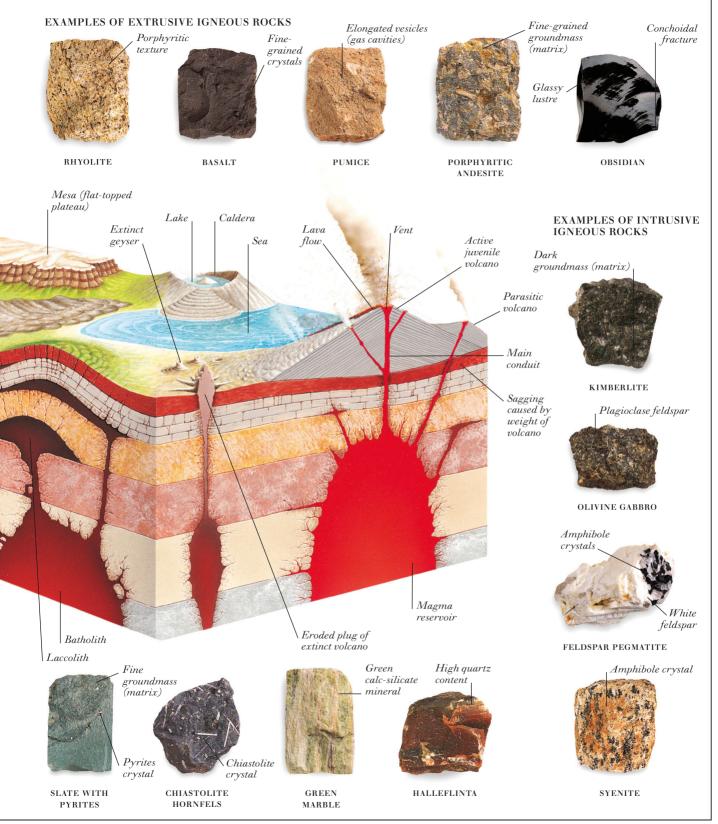


BASALT COLUMNS



Dark mineral

FOLDED SCHIST



Sedimentary rocks

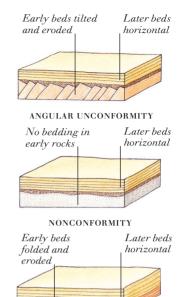
SEDIMENTARY ROCKS ARE FORMED BY THE ACCUMULATION and consolidation of sediments (see pp. 266-267). There are three main types of sedimentary rock. Clastic sedimentary rocks, such as breccia or sandstone, are formed from other rocks that have been broken down into fragments by weathering (see pp. 282-283), which have then been transported and deposited elsewhere. Organic sedimentary rocks—for example, coal (see pp. 280-281)—are derived from plant and animal remains. Chemical sedimentary rocks are formed by



THE GRAND CANYON, USA

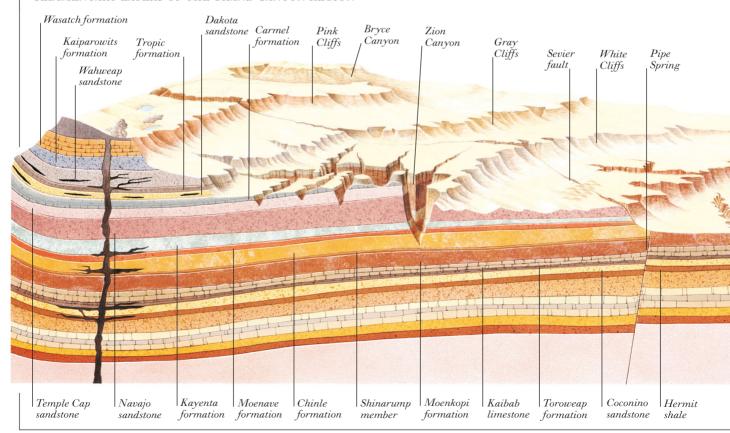
chemical sedimentary rocks are formed by chemical processes. For example, rock salt is formed when salt dissolved in water is deposited as the water evaporates. Sedimentary rocks are laid down in layers, called beds or strata. Each new layer is laid down horizontally over older ones. There are usually some gaps in the sequence, called unconformities. These represent periods in which no new sediments were being laid down, or when earlier sedimentary layers were raised above sea level and eroded away.

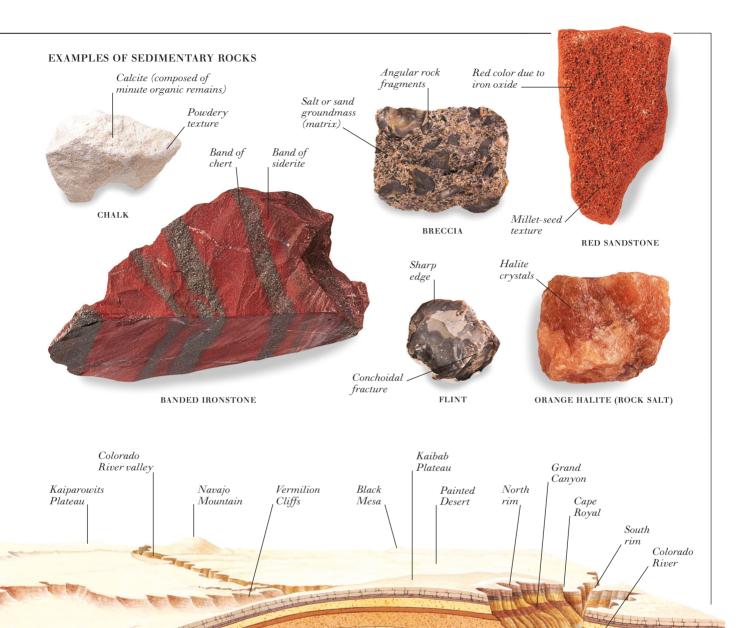
EXAMPLES OF UNCONFORMITIES



DISCONFORMITY

SEDIMENTARY LAYERS OF THE GRAND CANYON REGION





Supai

group

Redwall

limestone

Temple Butte

limestone

Muav

limestone

Bright Angel

shale

Shinumo

quartzite

formation

Hakatai

shale

Diabase

sill

Bass

formation

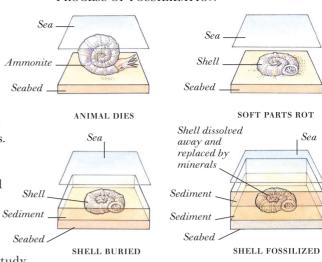
Tapeats

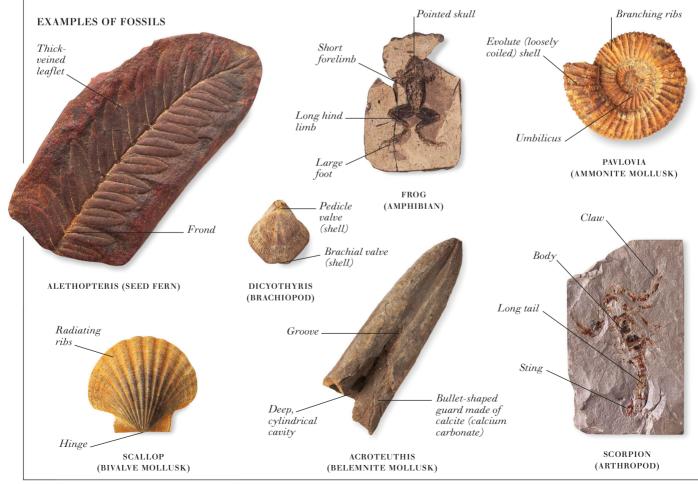
sandstone

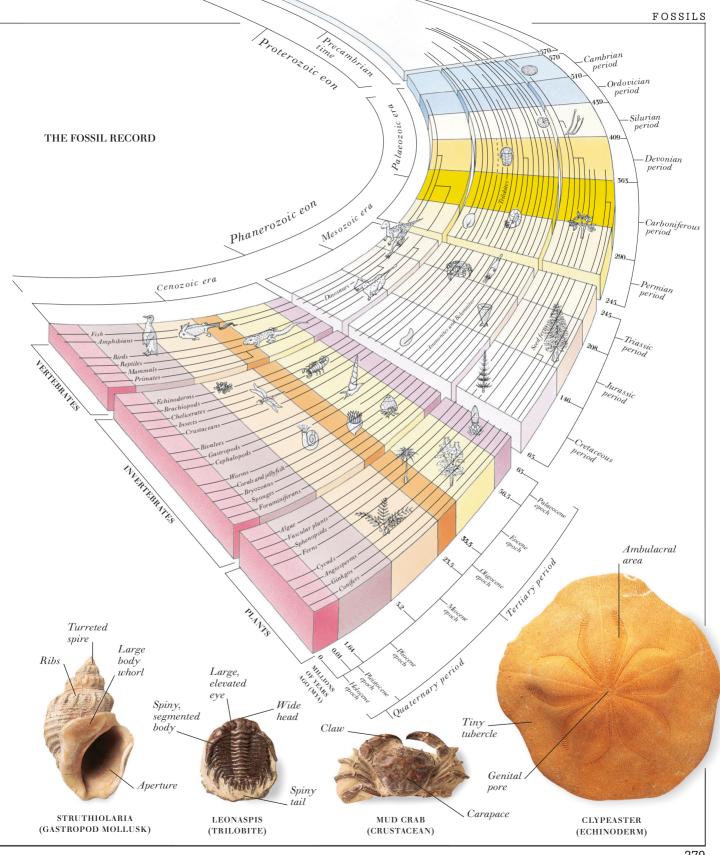
Fossils

FOSSILS ARE THE REMAINS of plants and animals that have been preserved in rock. A fossil may be the preserved remains of an organism itself, an impression of it in rock, or preserved traces (known as trace fossils) left by an organism while it was alive, such as organic carbon outlines, fossilized footprints, or droppings. Most dead organisms soon rot away or are eaten by scavengers. For fossilization to occur, rapid burial by sediment is necessary. The organism decays, but the harder parts bones, teeth, and shells, for example—may be preserved and hardened by minerals from the surrounding sediment. Fossilization may also occur even when the hard parts of an organism are dissolved away to leave an impression called a mold. The mold is filled by minerals, thereby creating a cast of the organism. The study of fossils (paleontology) can not only show how living things have evolved, but can also help to reveal the Earth's geological history—for example, by aiding in the dating of rock strata.

PROCESS OF FOSSILIZATION







Mineral resources

MINERAL RESOURCES CAN BE DEFINED AS naturally occurring substances that can be extracted from the Earth and are useful as fuels and raw materials. Coal, oil, and gas — collectively called fossil fuels — are commonly included in this group, but are not strictly minerals, because they are of organic origin. Coal formation begins when vegetation is buried and partly decomposed to form peat. Overlying sediments compress the peat and transform it into lignite (soft brown coal). As the overlying sediments



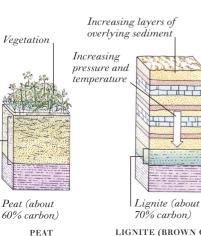
OIL RIG, NORTH SEA

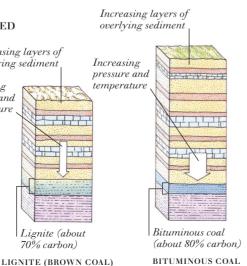
accumulate, increasing pressure and temperature eventually transform the lignite into bituminous and hard anthracite coals. Oil and gas are usually formed from organic matter that was deposited in marine sediments. Under the effects of heat and pressure, the compressed organic matter undergoes complex chemical changes to form oil and gas. The oil and gas percolate

upwards through water-saturated, permeable rocks and they may rise to the Earth's surface or accumulate below an impermeable layer of rock that has been folded or faulted to form a trap—an anticline (upfold) trap, for example. Minerals are inorganic substances that may consist of a single chemical element, such as gold, silver, or copper, or combinations of elements (see pp. 268-269). Some minerals are concentrated in mineralization zones in rock associated with crustal movements or volcanic activity. Others may be found in sediments as placer deposits—accumulations of high-density minerals that have been weathered out of rocks, transported, and

*About 80%*_deposited* (on riverbeds, for example).

HOW COAL IS FORMED





STAGES IN THE FORMATION OF COAL



PLANT MATTER

Decayed plant matter

About 60%

Crumbly ,

carbon About 70% carbon

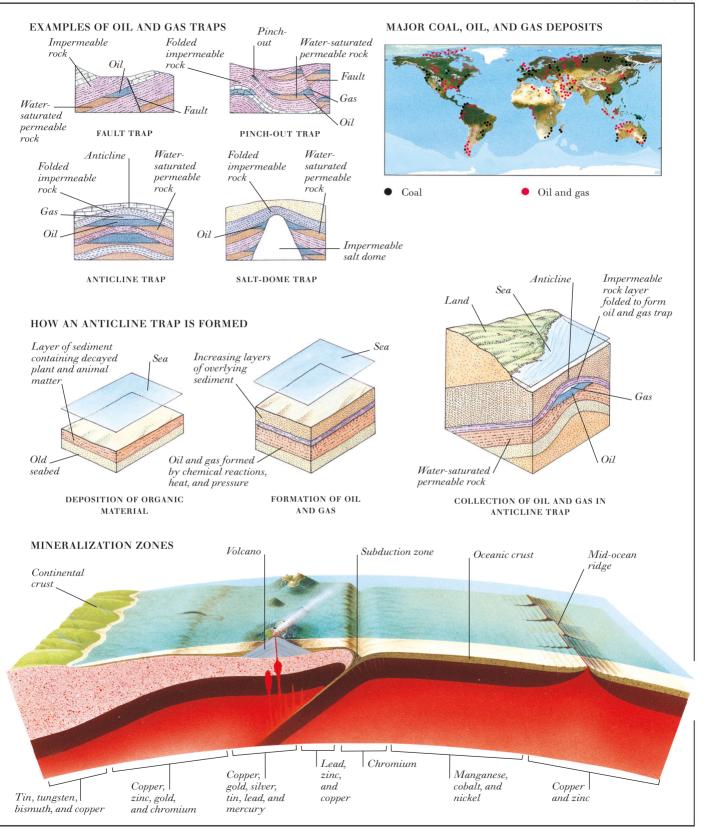
LIGNITE (BROWN COAL)

Powdery



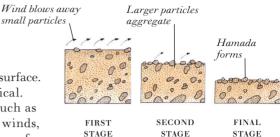


ANTHRACITE COAL



Weathering and erosion

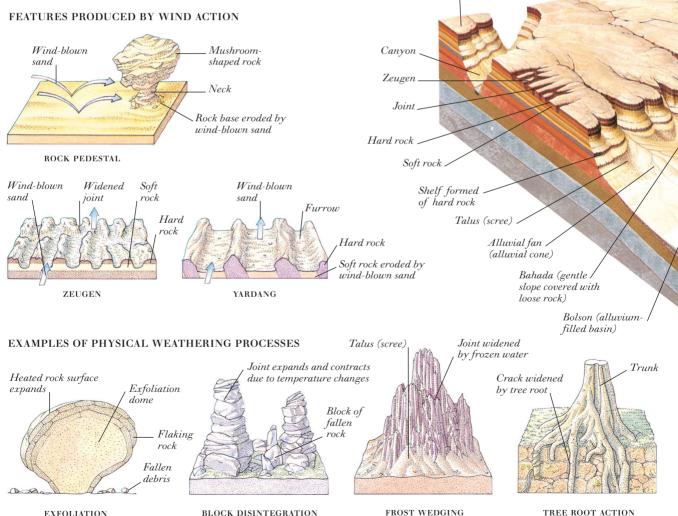
FORMATION OF A HAMADA (ROCK PAVEMENT)



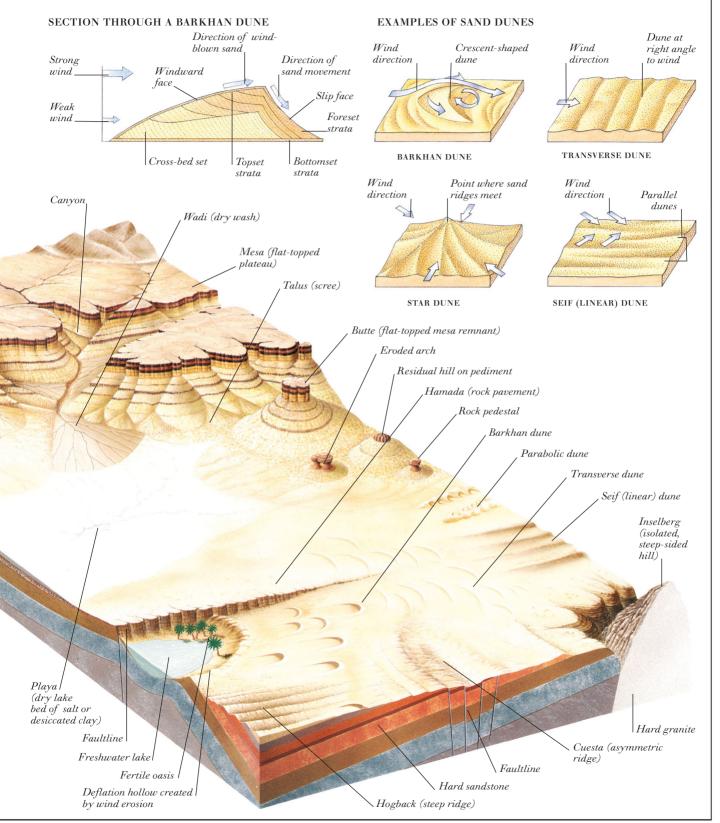
Mesa (flat-topped plateau)

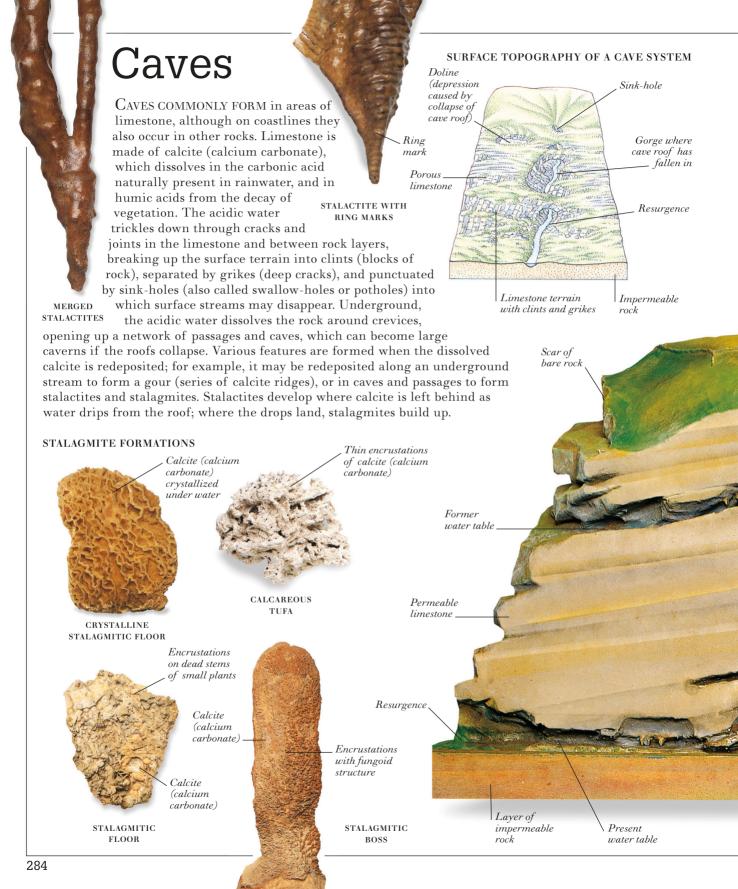
Weathering is the Breaking down of rocks on the Earth's surface. There are two main types: physical (or mechanical) and chemical. Physical weathering may be caused by temperature changes, such as freezing and thawing, or by abrasion from material carried by winds, rivers, or glaciers. Rocks may also be broken down by the actions of animals and plants, such as the burrowing of animals and the growth of roots. Chemical weathering causes rocks to decompose by changing their chemical composition—for example, rainwater may dissolve certain minerals in a rock. Erosion is the wearing away and removal of land surfaces by water, wind, or ice. It is greatest in areas of little or no surface vegetation, such as deserts, where sand dunes may form.

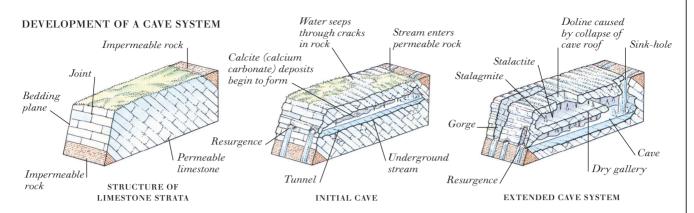
FEATURES OF WEATHERING AND EROSION

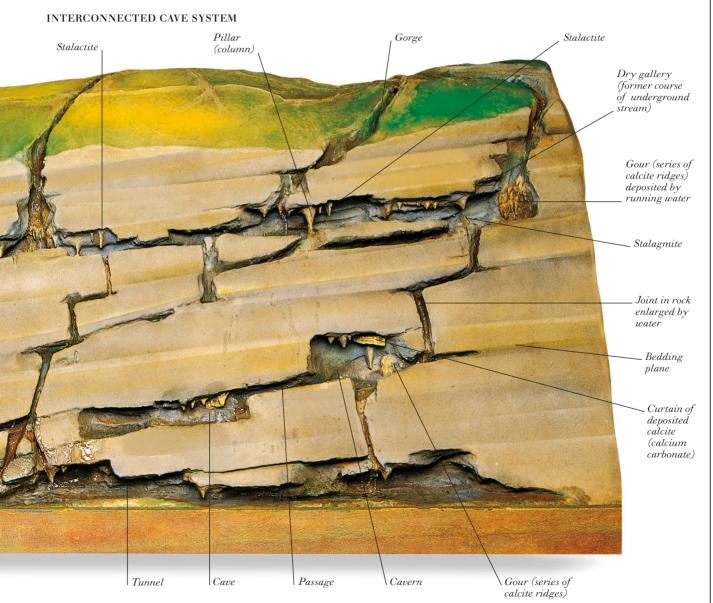


EXFOLIATION (ONION-SKIN WEATHERING)







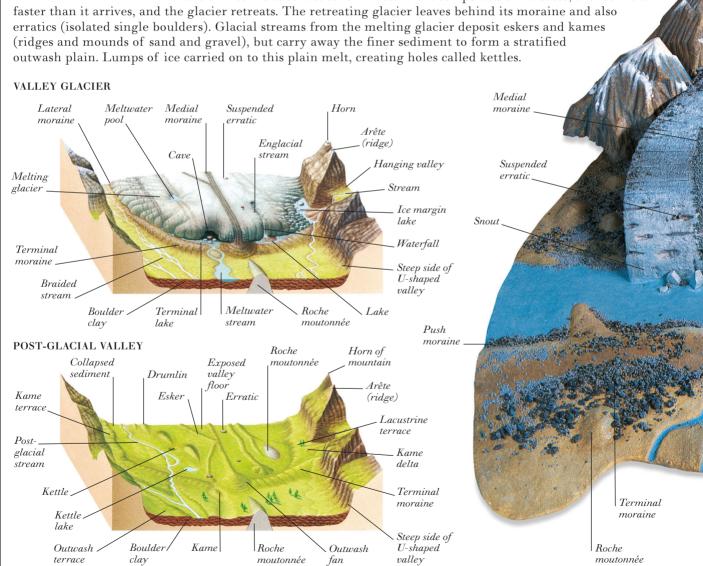


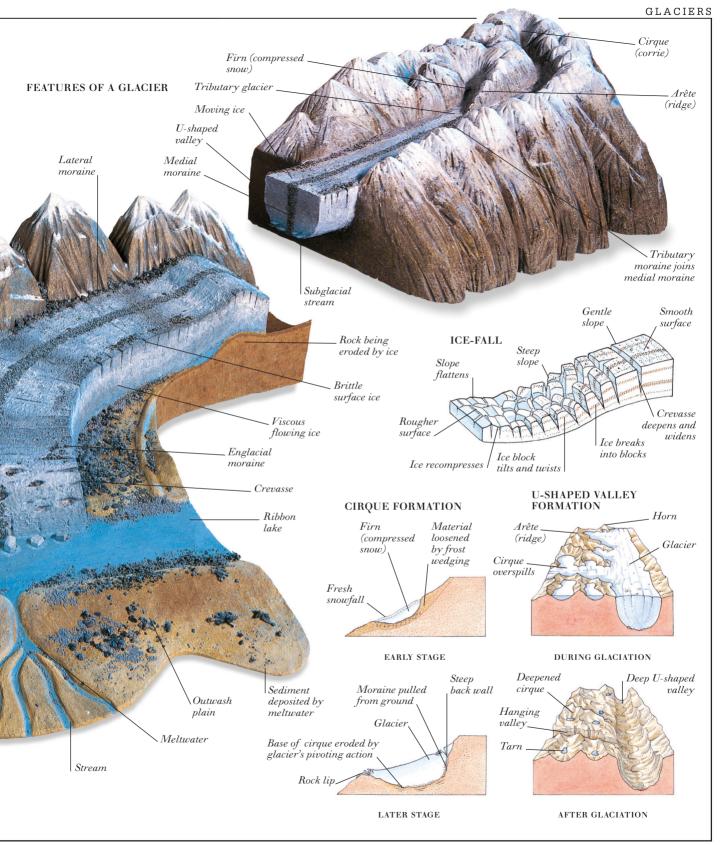
Glaciers



GLACIER BAY, ALASKA

A VALLEY GLACIER IS A LARGE MASS OF ICE that forms on land and moves slowly downhill under its own weight. It is formed from snow that collects in cirques (mountain hollows also known as corries) and compresses into ice as more and more snow accumulates. The cirque is deepened by frost wedging and abrasion (see pp. 282-283), and arêtes (sharp ridges) develop between adjacent cirques. Eventually, so much ice builds up that the glacier begins to move downhill. As the glacier moves it collects moraine (debris), which may range in size from particles of dust to large boulders. The rocks at the base of the glacier erode the glacial valley, giving it a U-shaped cross-section. Under the glacier, roches moutonnées (eroded outcrops of hard rock) and drumlins (rounded mounds of rock and clay) are left behind on the valley floor. The glacier ends at a terminus (the snout), where the ice melts as fast as it arrives. If the temperature increases, the ice melts





Rivers

RIVERS FORM PART of the water cycle—the continuous circulation of water between the land, sea, and atmosphere. The source of a river may be a mountain spring or lake, or a melting glacier. The course that the river subsequently takes depends on the slope of the terrain and on the rock types and formations over which it flows. In its early, upland stages, a river tumbles steeply over rocks and boulders and cuts a steep-sided V-shaped valley. Farther downstream, it flows smoothly over sediments and forms winding meanders, eroding sideways to create broad valleys and plains. On reaching the coast, the river may deposit sediment to form an estuary or delta (see pp. 290-291).

River River

RIVER CAPTURE

Tributary erodes DryRiver captured headwards vallev by tributary River flow decreases River flow increases. EARLY STAGE LATER STAGE

THE WATER CYCLE falls on high ground Wind Water Water vapor released carried into atmosphere by downstream trees and other plants by river Wind

Precipitation

RIVER DELTA, BANGLADESH

SATELLITE IMAGE OF GANGES

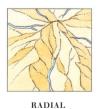
Distributary Large volume of sediment

Water vapor forms clouds Ganges River Ganges delta

Water evaporates from sea Water stored in sea

Water evaporates from lake River flows into sea Water seeps underground and flows to sea

RIVER DRAINAGE PATTERNS



Infertile

swampland

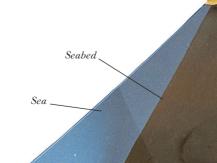
CENTRIPETAL



PARALLEL

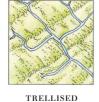


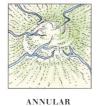






DERANGED

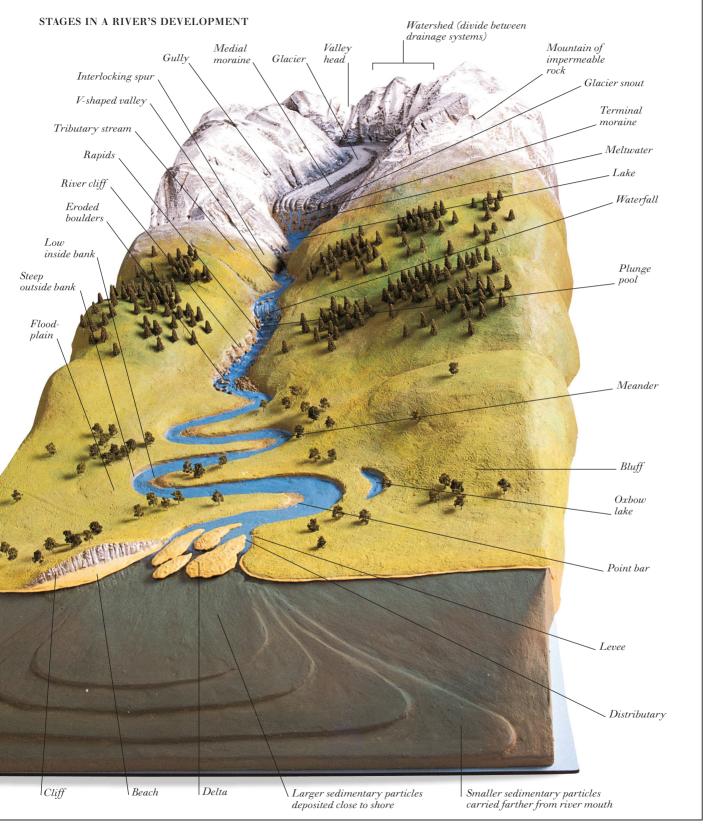






Sediment layers

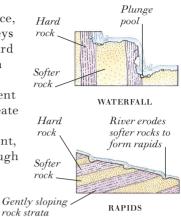
288



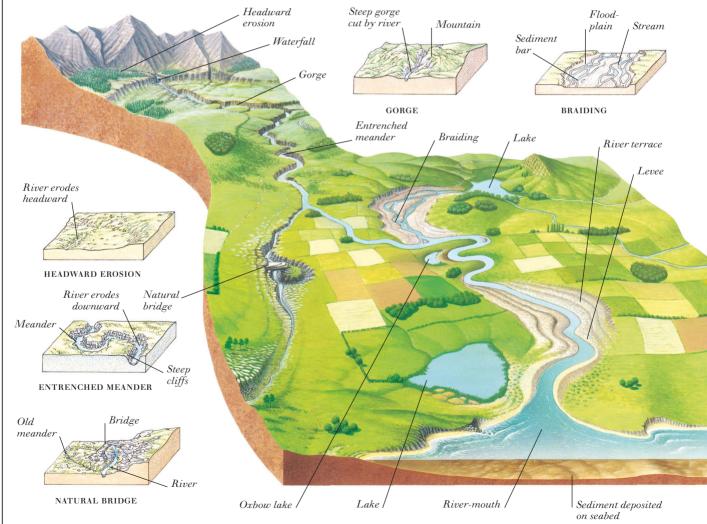
River features

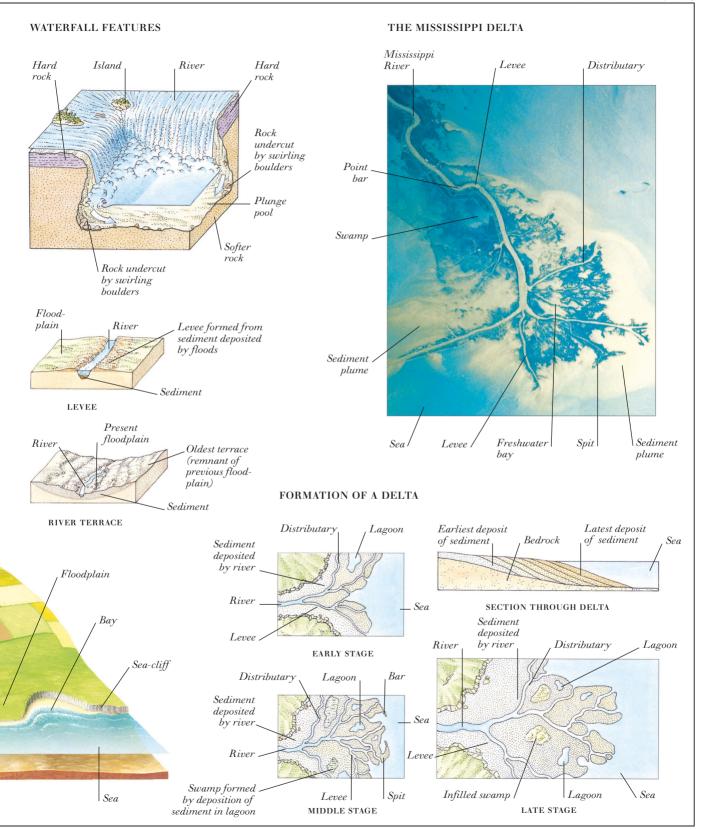
RIVERS ARE ONE OF THE MAJOR FORCES that shape the landscape. Near its source, a river is steep (see pp. 288-289). It erodes downward, carving out V-shaped valleys and deep gorges. Waterfalls and rapids are formed where the river flows from hard rock to softer, more easily eroded rock. Farther downstream, meanders may form and there is greater sideways erosion, resulting in a broad river valley. The river sometimes erodes through the neck of a meander to form an oxbow lake. Sediment deposited on the valley floor by meandering rivers and during floods helps to create a floodplain. Floods may also deposit sediment on the banks of the river to form levees. As a river spills into the sea or a lake, it deposits large amounts of sediment, and may form a delta. A delta is an area of sand bars, swamps, and lagoons through which the river flows in several channels called distributaries—the Mississippi delta, for example. Often, a rise in sea level may have flooded the river mouth to form a broad estuary, a tidal section where seawater mixes with fresh water.

HOW WATERFALLS AND RAPIDS ARE FORMED









Lakes and groundwater

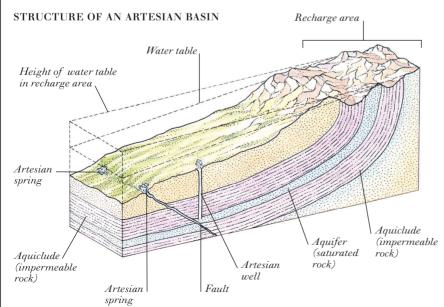
Natural lake occur where a large quantity of water collects in a hollow in impermeable rock, or is prevented from draining away by a barrier, such as moraine (glacial deposits) or solidified lava. Lakes are often relatively short-lived landscape features, as they tend to become silted up by sediment from the streams and rivers that feed them. Some of the more long-lasting



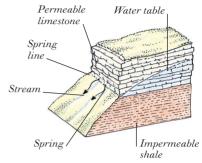
LAKE BAIKAL, RUSSIA

lakes are found in deep rift valleys formed by vertical movements of the Earth's crust (see pp. 58-59)—for example, Lake Baikal in Russia, the world's largest freshwater lake, and the Dead Sea in the Middle East, one of the world's saltiest lakes. Where water is able to drain away, it sinks into the ground until it reaches a layer of impermeable rock, then accumulates in the permeable rock above it; this water-saturated permeable rock is called an aquifer. The saturated zone varies in depth according to seasonal and climatic changes. In wet conditions, the water

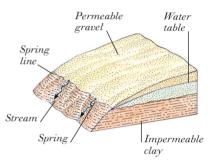
stored underground builds up, while in dry periods it becomes depleted. Where the upper edge of the saturated zone—the water table—meets the ground surface, water emerges as springs. In an artesian basin, where the aquifer is below an aquiclude (layer of impermeable rock), the water table throughout the basin is determined by its height at the rim. In the center of such a basin, the water table is above ground level. The water in the basin is thus trapped below the water table and can rise under its own pressure along faultlines or well shafts.



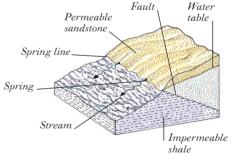
EXAMPLES OF SPRINGS



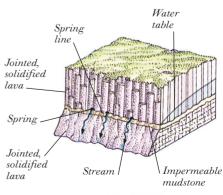
LIMESTONE SPRING



COASTAL (VALLEY) SPRING



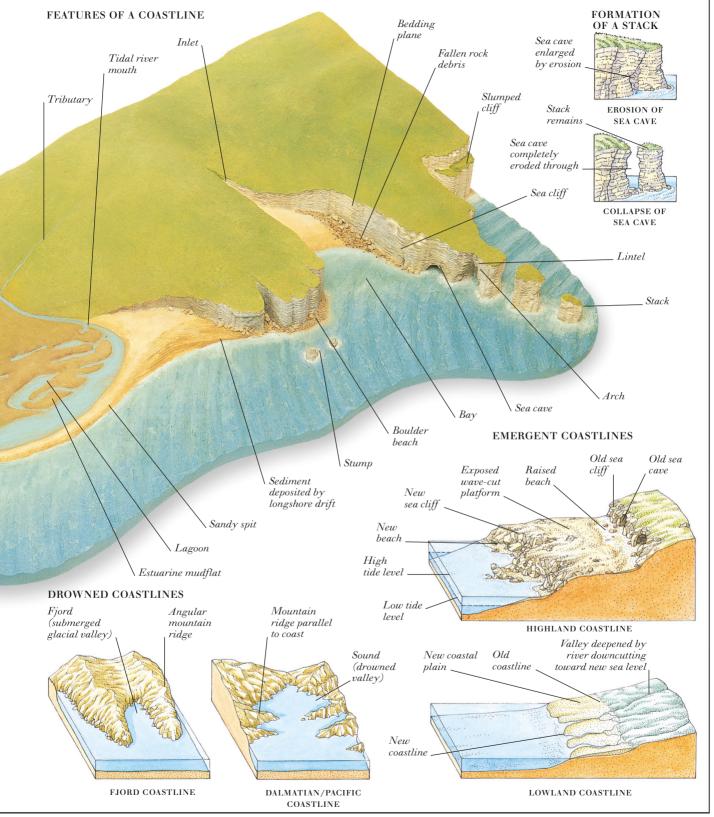
FAULT SPRING



LAVA SPRING

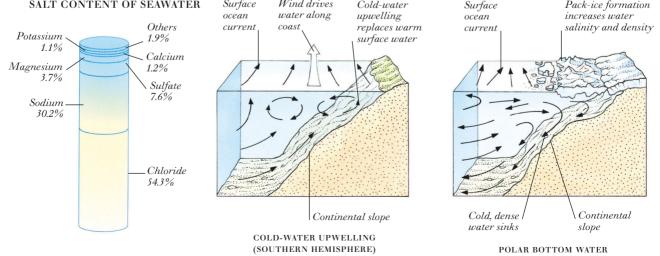
FEATURES OF A GROUNDWATER SYSTEM Zone of aeration Layer LakeStream of soil moisture Zone of aeration Marsh Capillary fringe Water table Saturated. CLOSE-UP OF SURFACE LAYER Permanently saturated zone Dry-season (saturated in wet water table Temporarily saturated and dry seasons) zone (saturated only in Present water wet season) THE DEAD SEA, ISRAEL/JORDAN table (wet season) EXAMPLES OF LAKES Lake in kettle Oxbow lake (cut-off river Glacial(former site of deposits ice block) meander) River River KETTLE LAKE OXBOW LAKE Jordan CalderaMovementVolcanic Strike-slip (collapsed lake along strike-(lateral) fault slip (lateral) crater) fault Dead Sea Lake in elongated Steep rift-VOLCANIC LAKE hollow valley walls STRIKE-SLIP (LATERAL) FAULT LAKE Rift valle Steep back wall Moraine eroded by frost or rock lip and ice. damming lake Salt left by evaporation Israel Highvalley Tarn (circular Sinking graben Shallowwalls (block fault) mountain lake) Jordan flats GRABEN (BLOCK-FAULT) LAKE TARN

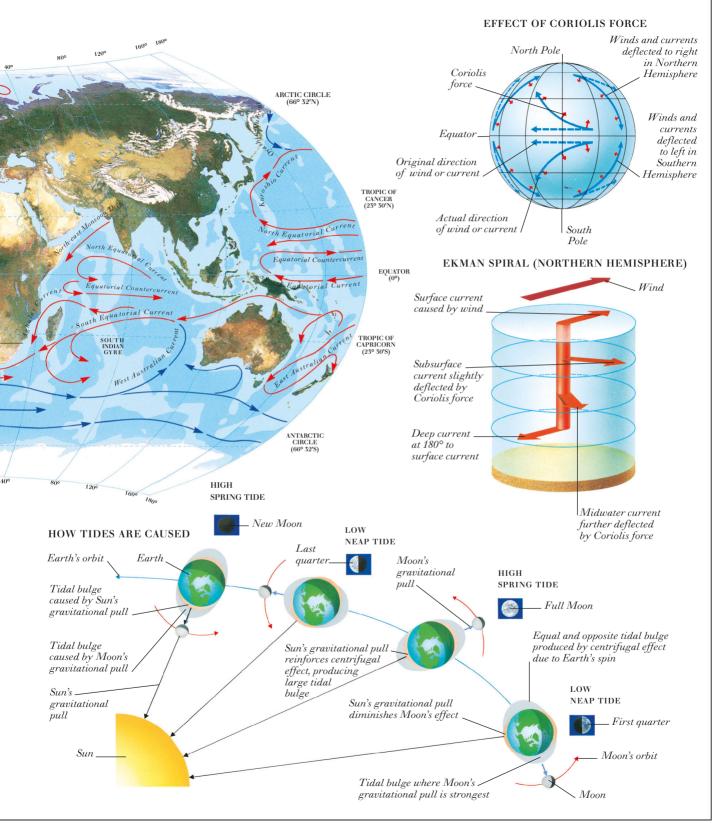
Coastlines FEATURES OF A SEA CLIFF Cliff-face High tide COASTLINES ARE AMONG THE MOST RAPIDLY changing landscape Low tide lenel features. Some are eroded by waves, wind, and rain, causing level cliffs to be undercut and caves to be hollowed out of solid rock. Others are built up by waves transporting sand and small rocks in a process known as longshore drift, and by rivers depositing sediment in deltas. Additional influences include the activities of living organisms Offshore. Undercut Wave-cut such as coral, crustal movements, and sea-level variations due to deposits platform area of cliff climatic changes. Rising land or a drop in sea level creates an emergent coastline, with cliffs and beaches stranded above the new shoreline. Sinking land or a rise in sea level produces a drowned coastline, typified Mature river by fjords (submerged glacial valleys) or submerged river valleys. FEATURES OF WAVES Trough Wave Shorter wavelength Wavelength height near beach Headland Bedding plane Circular orbit of water Orbit deformed into ellipse and suspended particles as water gets shallower LONGSHORE DRIFT Movement of Buildup material of material Backwash along beach against groyne Pebble Sea cliff Beach Remnants of Grovne former headland Waves approaching Estuary shore at an Swash oblique angle zone Swash DEPOSITIONAL FEATURES OF COASTLINES Wave Wave Wave Cuspate Wave Barrier Bay head foreland direction beach direction direction Tombolo direction beach Headland IslandLagoon BAY HEAD BEACH TOMBOLO CUSPATE FORELAND BARRIER BEACH



Oceans and seas SURFACE CURRENTS GREENWICH MERIDIAN OCEANS AND SEAS COVER ABOUT 70 PERCENT of the Earth's surface and account for about 97 percent of its total water. These oceans and seas play a crucial role in regulating temperature variations and determining climate. Their waters absorb heat from the Sun, especially in tropical regions, and the surface currents distribute it around the Earth, warming overlying air masses and neighboring land in winter and cooling them in summer. The oceans are never still. Differences orth Equatorial Cur. in temperature and salinity drive Equatorial Countercurren deep current systems, while surface currents are generated by winds South Equatorial Current blowing over the oceans. All currents are deflected—to the right in the Northern Hemisphere, to the left in the Southern Hemisphere—as a result of the Earth's rotation. This deflective factor is known as the Coriolis force. A current that begins on the surface is immediately deflected. This current in turn generates a current in the layer of water Antarctic Circumpolar Current beneath, which is also deflected. As the movement is transmitted downward, the deflections form an Ekman spiral. The waters of the oceans and seas are also moved by the constant ebb and flow of tides. These are caused by the gravitational pull of the Moon and Sun. GREENWICH The highest tides (Spring tides) occur at full and new Moon; the lowest tides (neap tides) occur at first and last quarter.

SALT CONTENT OF SEAWATER Surface Wind drives Cold-water Surface Pack-ice formation





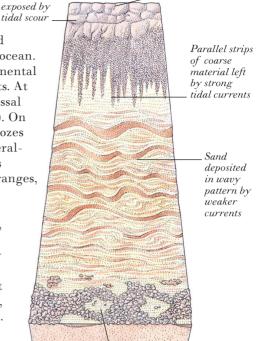
The ocean floor

CONTINENTAL-SHELF FLOOR

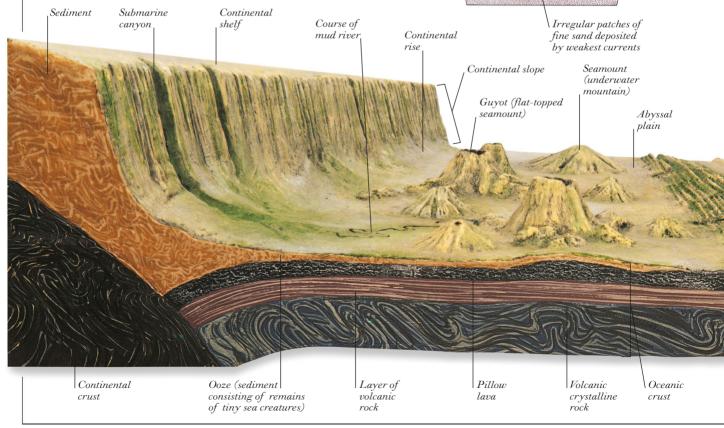
Shoreline

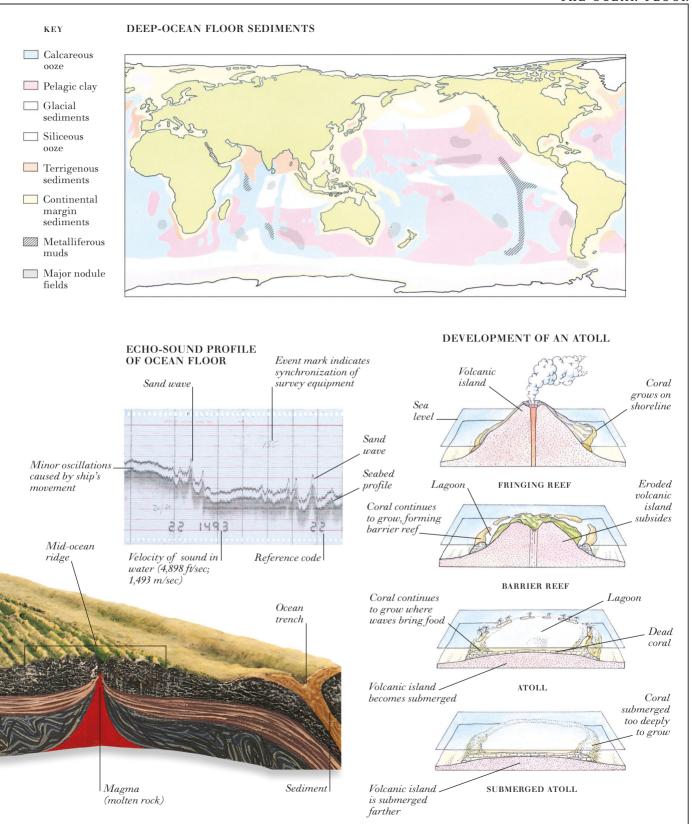
Bedrock

tidal scour THE OCEAN FLOOR COMPRISES TWO SECTIONS: the continental shelf and slope, and the deep-ocean floor. The continental shelf and slope are part of the continental crust, but may extend far into the ocean. Sloping quite gently to a depth of about 460 feet (140 m), the continental shelf is covered in sandy deposits shaped by waves and tidal currents. At the edge of the continental shelf, the seabed slopes down to the abyssal plain, which lies at an average depth of about 12,500 feet (3,800 m). On this deep-ocean floor is a layer of sediment made up of clays, fine oozes formed from the remains of tiny sea creatures, and occasional mineralrich deposits. Echo-sounding and remote sensing from satellites has revealed that the abyssal plain is divided by a system of mountain ranges, far bigger than any on land—the mid-ocean ridge. Here, magma (molten rock) wells up from the Earth's interior and solidifies, widening the ocean floor (see pp. 58-59). As the ocean floor spreads, volcanoes that have formed over hot spots in the crust move away from their magma source; they become extinct and are increasingly submerged and eroded. Volcanoes eroded below sea level remain as seamounts (underwater mountains). In warm waters, a volcano that projects above the ocean surface often acquires a fringing coral reef, which may develop into an atoll as the volcano becomes submerged.



FEATURES OF THE OCEAN FLOOR





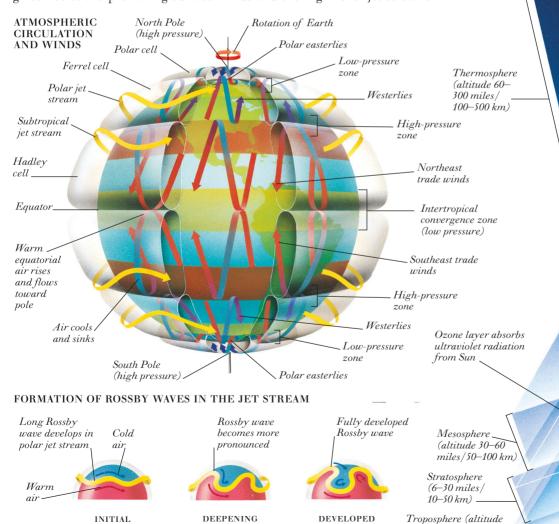
The atmosphere

Exosphere _________(altitude above 300 miles/500 km)



The Earth Is Surrounded by Its atmosphere, a blanket of gases that enables life to exist on the planet. This layer has no definite outer edge, gradually becoming thinner until it merges into space, but over 80 percent of atmospheric gases are held by gravity within about 12 miles (20 km) of the Earth's surface. The atmosphere blocks out much harmful ultraviolet solar radiation, and insulates the Earth against extremes of temperature by limiting both incoming solar radiation and the escape of reradiated heat into space.

This natural balance may be distorted by the greenhouse effect, as gases such as carbon dioxide have built up in the atmosphere, trapping more heat. Close to the Earth's surface, differences in air temperature and pressure cause air to circulate between the equator and poles. This circulation, together with the Coriolis force, gives rise to the prevailing surface winds and the high-level jet streams.



WAVE

WAVE

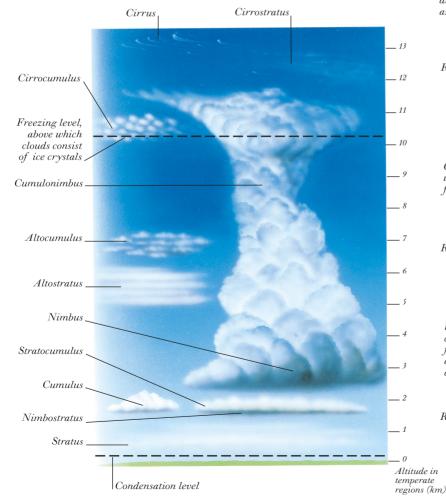
to 6 miles / 10 km)

UNDULATION

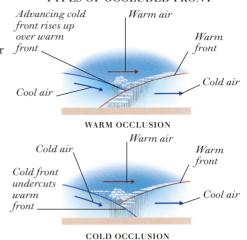
Weather

Weather is defined as the atmospheric conditions at a particular time and place; climate is the average weather conditions for a given region over time. Weather is assessed in terms of temperature, wind, cloud cover, and precipitation, such as rain or snow. Good weather is associated with high-pressure areas, where air is sinking. Cloudy, wet, changeable weather is common in low-pressure zones with rising, unstable air. Such conditions occur at temperate latitudes, where warm air meets cool air along the polar fronts. Here, spiraling low-pressure cells known as depressions (mid-latitude cyclones) often form. A depression usually contains a sector of warmer air, beginning at a warm front and ending at a cold front. If the two fronts merge, forming an occluded front, the warm air is pushed upward. An extreme form of low-pressure cell is a hurricane (also called a typhoon or tropical cyclone), which brings torrential rain and exceptionally strong winds.

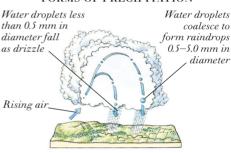
TYPES OF CLOUD



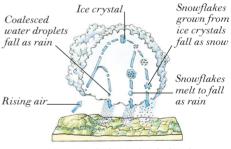
TYPES OF OCCLUDED FRONT



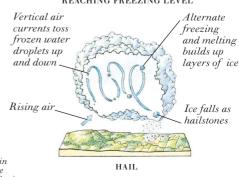
FORMS OF PRECIPITATION

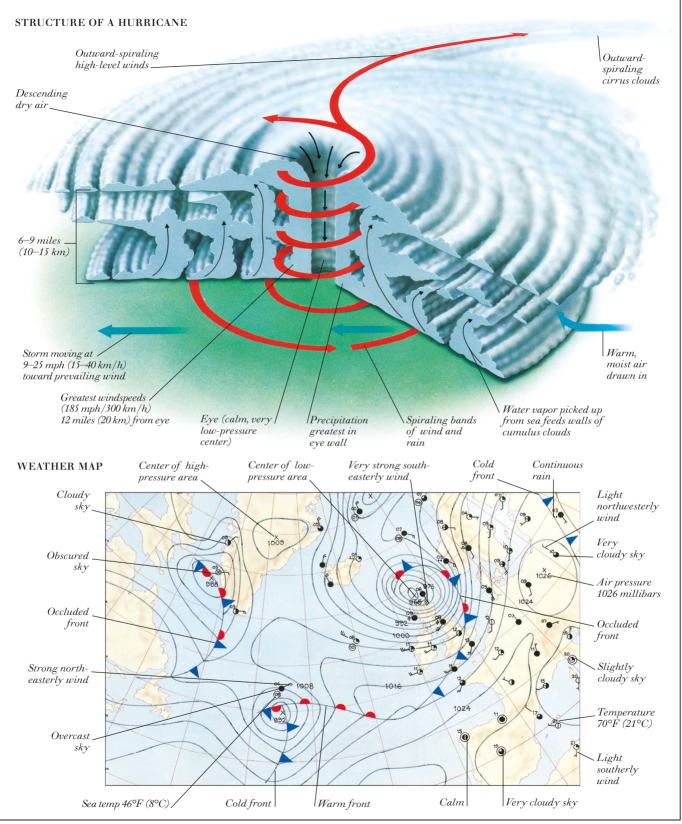


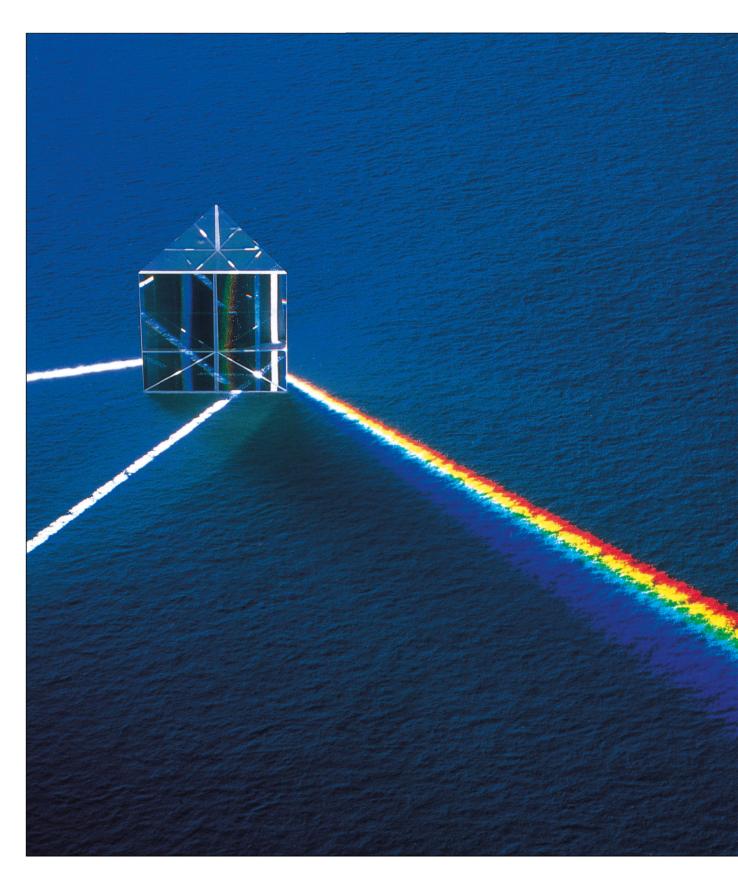
RAIN FROM CLOUDS NOT REACHING FREEZING LEVEL



RAIN AND SNOW FROM CLOUDS REACHING FREEZING LEVEL









Physics and Chemistry

The Variety of Matter 306
ATOMS AND MOLECULES
THE PERIODIC TABLE 310
CHEMICAL REACTIONS 312
Energy 314
ELECTRICITY AND MAGNETISM 316
Light
FORCE AND MOTION 320



The variety of matter



PLANT AND INSECT (LIVING MATTER)

Matter is anything that has a mass. It includes everything from natural substances, such as minerals or living organisms, to synthetic materials. Matter can exist in three distinct states—solid, liquid, and gas. A solid is rigid and retains its shape. A liquid is fluid, has a definite volume, and will take the shape of its container. A gas (also fluid) fills a space, so its volume will be the same as the volume of its container. Most substances can exist as a solid, a liquid, or a gas: the state

is determined by temperature. At very high temperatures, matter becomes plasma, often considered to be a fourth state of matter. All matter is composed of microscopic particles, such as atoms and molecules (see pp. 308-309). The arrangement and interactions of these particles give a substance

its physical and chemical properties, by which matter can be identified. There is a huge variety of matter because particles can arrange themselves in countless ways, in one substance or by mixing with others. Natural glass, for example, seems to be a solid but is, in fact, a supercool liquid: the atoms are not locked into a pattern and can flow. Pure substances known as elements (see p. 310) combine to form compounds or mixtures. Mixtures called colloids are made up of larger particles of matter suspended in a solid, liquid, or gas, while a solution is one substance dissolved in another.

TYPES OF COLLOID



HAIR GEL (SOLID IN LIQUID)

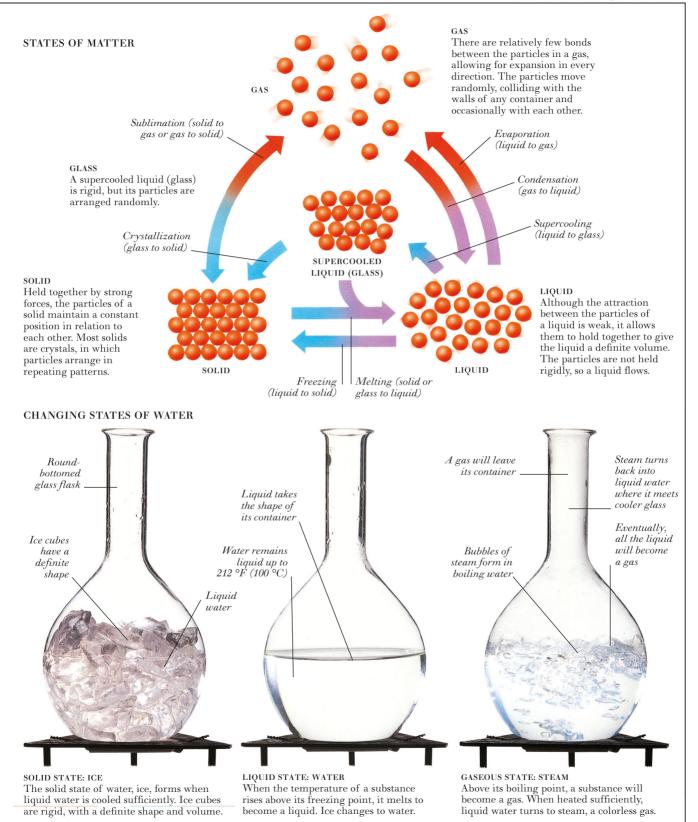


MIST (LIQUID IN GAS)

SHAVING CREAM (AIR IN LIQUID)

EXAMPLES OF MATTER





Atoms and molecules

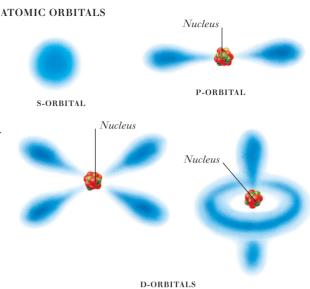


FALSE-COLOR IMAGE OF ACTUAL GOLD ATOMS

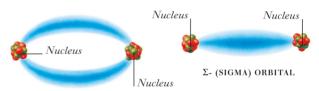
ATOMS ARE THE smallest individual parts of an element (see pp. 310-311). They are tiny, with diameters in the order of one ten-thousand-millionth of a meter (10⁻¹⁰ m). Two or more atoms join together (bond) to form a molecule of a substance known as a compound. For example, when atoms of the elements hydrogen and fluorine join together, they form a molecule of the compound hydrogen fluoride. So molecules are the smallest

individual parts of a compound. Atoms themselves are not indivisible—they possess an internal structure. At their center is a dense nucleus, consisting of protons, which have a positive electric charge (see p. 316), and neutrons, which are uncharged. Around the nucleus are the negatively charged electrons. It is the electrons that give a substance most of its physical and chemical properties. They do not follow definite paths around the nucleus. Instead, electrons are said to be found within certain regions, called orbitals. These are arranged around the nucleus in "shells," each containing electrons of a particular energy. For example, the first shell (1) can hold up to two electrons, in a so-called s-orbital (1s). The second shell (2) can hold up to eight electrons, in s-orbitals (2s) and p-orbitals (2p). If an atom loses an electron, it becomes a positive ion (cation). If an electron is gained, an atom becomes a negative ion (anion). Ions of opposite charges will attract and join together, in a type of bonding known as ionic bonding. In covalent bonding, the atoms bond by sharing their electrons in what become molecular orbitals.

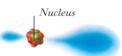
ATOM (F)



MOLECULAR ORBITALS

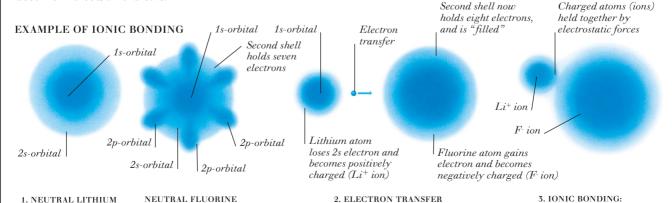


π- (PI) ORBITAL

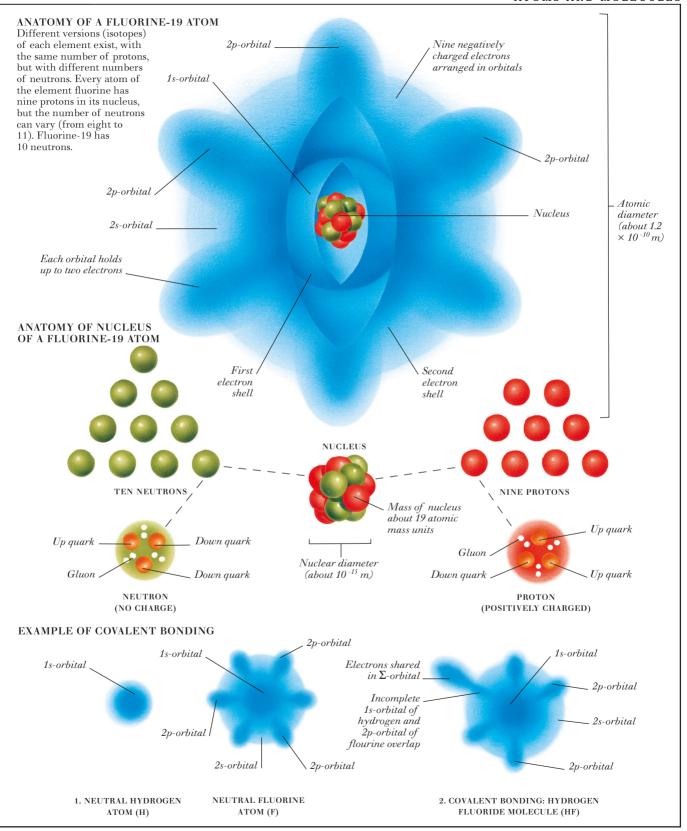


SP3-HYBRID ORBITAL

LITHIUM FLUORIDE MOLECULE (LiF)



ATOM (Li)



The periodic table

AN ELEMENT is a substance that consists of atoms of one type only. The 92 elements that occur naturally, and the 17 elements created artificially, are often arranged into a chart called the periodic table. Each element is defined by its atomic number—the number of protons in the nucleus of each of its atoms (it is also the number of electrons present). Atomic number increases along each row (period) and down each column (group). The shape of the table is determined by the way in which electrons arrange themselves around the nucleus: the positioning of elements in order of increasing atomic number brings together atoms with a similar pattern of orbiting electrons (orbitals). These appear in blocks. Electrons occupy shells of a certain energy (see pp. 308-309). Periods are ordered according to the filling of successive shells with electrons, while groups reflect the number of electrons in the outer shell (valency electrons). These outer electrons are important—they decide the chemical properties of the atom. Elements that appear in the same group have similar properties because they have the same number of electrons in their outer shell. Elements in Group 0 have "filled shells," where the outer shell holds its maximum number of electrons, and are stable. Atoms of Group I elements have just one electron in their outer shell. This makes them unstable—and ready to react with other substances.

METALS AND NON-METALS

Elements at the left-hand side of each period are metals. Metals easily lose electrons and form positive ions. Nonmetals, on the right of a period, tend to become negative ions. Semimetals, which have properties of both metals and non-metals, are between the two.

Chemical symbol Chemical name Group I Hydrogen Atomic number is Relative atomic mass number of protons in each nucleus Н RELATIVE ATOMIC MASS Atomic mass (formerly atomic Hydrogen Group II weight) is the mass of each atom 1.0 Atomic number of an element. It is equal to the goes up by one number of protons plus the 3 along each number of neutrons (electrons Li Be period have negligible mass). The figures Lithium Bervllium given are the averages for all the 9.0 different versions (isotopes) of each element, measured relative 11 to the mass of carbon-12 Na Mg Sodium Magnesium 1st transition metals 23.0 24.3 23 25 19 22 24 20 Sc Ti \mathbf{V} K Cr Mn Ca Scandium Vanadium Chromium Manganese Potassium Titanium Calcium 39.1 45.0 47.9 52.0 40.1 42 37 39 40 43 Rb Y Zr Tc Nb Mo Sr Technetium Rubidium Yttrium Zirconium Niobium Molybdenum Strontium 85.5 88.9 91.2 92.9 95.9 (98)87.6 55 56 57-71 72 73 74 75 Hf Ta W Cs Re Ba Cesium Barium Hafnium Tantalum Tungsten Rhenium 132.9 137.3 178.5 180.9 183.8 186.2 88 89-103 104 105 106 107 Fr Sg Rf Ra Db BhFrancium Radium Rutherfordium Dubnium eaborgium Bohrium 223.0 226.0 (267)(268)(271)(270)

Soft, silvery, and highly reactive metal

s-block





metal

Two series always separated out from

the table to give it a coherent shape

Silvery.

reactive



Atomic number

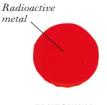
Hard. silvery metal

d-block

MAGNESIUM: GROUP 2 METAL

CHROMIUM: 1ST TRANSITION METAL

TYPES OF ELEMENT KEY:	
Alkali metals	Poor metals
Alkaline earth metals	Semi-metals
Transition metals	Non-metals
Lanthanides	Noble gases
Actinides	Unknown chemica properties



PLU	TONIUM	1:
CTINIDE	SERIES	METAL

57	58	59	60		
La	Ce	Pr	Nd		
Lanthanum	Cerium	Praseodymium	Neodymium		
138.9	140.1	140.9	144.2		
89	90	91	92		
Ac	Th	Pa	U		
Actinium	Thorium	Protactinium	Uranium		
(227)	232.0	231.0	238.0		



DIAMOND

ALLOTROPES OF CARBON Some elements exist in more than one formthese are known as allotropes. Carbon powder, graphite, and diamond are allotropes of carbon. They

physical properties.

all consist of carbon atoms, carbon groups but have very different

SULFUR: GROUP 6 SOLID NON-METAL Boron and



IODINE: **GROUP 7** SOLID NON-METAL



9

Purple-black solid turns to gas easily

Group 0

Nitrogen and oxygen groups

	carbon	groups	oxygen	groups	Halogens
(Group III	Group IV	$Group\ V$	Group VI	Group VII

N







28

Ni

Nickel

78

(281)

	,
CARBON POWDER	i.

30

Zn

Zinc

5 B C Boron Carbon 10.8 12.0 13 14

Nitrogen 14.0 15

Oxygen 16.0 16

34

Se

Selenium

79.0

()

F Ne Fluorine 19.0 20.2 17 18

Short period

GRAPHITE 2nd transition metals

27

3rd transition metals

29

Cu

79

Au

(281)

	A1
	Aluminum
7	27.0
	31

Ga

Gallium

69.7

A 1

Si Silicon 28.1 32

Ge

Germanium

72.6

P Phosphorus 31.0

33

As

Arsenio

74.9

S Sulfur 32.1

C1Ar Chlorine Argon 35.5 40.0

Long period

Fe	Co
Iron	Cobalt
55.8	58.9
44	45
Ru	Rh
uthenium	Rhodium





65.4 48 Cd Cadmium

112.4

80

Hg

Copernicium

(285)





82

Pb



121.8

83

52 Te Tellurium 127.6

53 T Iodine 126.9

85

Uus

Ununseptium

(294)

35

Br

Bromine

79.9



36

 Kr

Krypton

83.8

86

Uuo

Ununoctium

(294)



Hassium

(269)

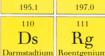
101.1





77









Uut

Ununtrium

(286)

81





Uuq

Ununquadium

(289)

p-block

Bi Bismuth 209.0 115

Uup

Ununpentium

(289)

Po Polonium (209)116

Uuh

Ununhexium

(293)

84







gas glows red in discharge tube



GOLD: 3RD TRANSITION METAL



GROUP 4 POOR METAL



NOBLE GASES

Group 0 contains elements that have a filled (complete) outer shell of electrons, which means the atoms do not need to lose or gain electrons by bonding with other atoms. This makes them stable and they do not easily form ions or react with other elements. Noble gases are also called GROUP 5 SEMI-METAL rare or inert gases.

NEON: GROUP 0 COLORLESS GAS

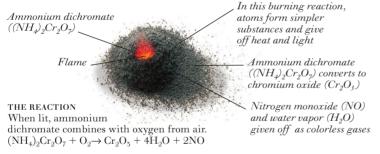
Promethium (145)	62 Sm Samarium 150.4	Europium	64 Gd Gadolinium 157.3	Tb Terbium 158.9	Dy Dysprosium 162.5	Holmium 164.9	Erbium 167.3	Tm Thulium 168.9	Yb Ytterbium 173.0	Lutetium
95 Np Neptunium (237)	Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	Es Einsteinium (252)	Fermium (257)	101 Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)

f-block

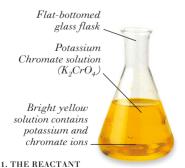
Chemical reactions

A CHEMICAL REACTION TAKES PLACE whenever bonds between atoms are broken or made. In each case, atoms or groups of atoms rearrange, making new substances (products) from the original ones (reactants). Reactions happen naturally, or can be made to happen; they may take years, or only an instant. Some of the main types are shown here. A reaction usually involves a change in energy (see pp. 314-315). In a burning reaction, for example, the making of new bonds between atoms releases energy as heat and light. This type of reaction, in which heat is given off, is an exothermic reaction. Many reactions, like burning, are irreversible, but some can take place in either direction, and are said to be reversible. Reactions can be used to form solids from solutions: in a double decomposition reaction, two compounds in solution break down and re-form into two new substances, often creating a precipitate (insoluble solid); in displacement, an element (e.g., copper) displaces another element (e.g., silver) from a solution. The rate (speed) of a reaction is determined by many different factors, such as temperature, and the size and shape of the reactants. To describe and keep track of reactions, internationally recognized chemical symbols and equations are used. Reactions are also used in the laboratory to identify matter. An experiment with candle wax, for example, demonstrates that it contains carbon and hydrogen.

BURNING MATTER



A REVERSIBLE REACTION



1. THE REACTANT Potassium chromate dissolves in water to form potassium ions and chromate ions. $K_2CrO_4 \rightarrow 2K^+ + CrO_4^2$

Pipette Hydrochloric acid (HCl) added in drops Acid causes reaction to take place Chromate ions converted to orange dichromate ions Potassium dichromate (KCr₂O₇) forms 2. THE REACTION

Addition of hydrochloric acid changes chromate ions into dichromate ions. $2\text{CrO}_4^{2-} \rightarrow \text{Cr}_2\text{O}_7^{2-}$

SALT FORMATION (ACID ON METAL)

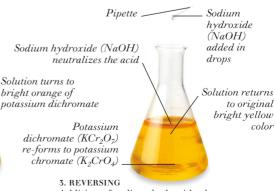


THE REACTION Hydrochloric acid added to zinc produces zinc chloride and hydrogen. Zn + 2HCl \rightarrow ZnCl₂ + H₂

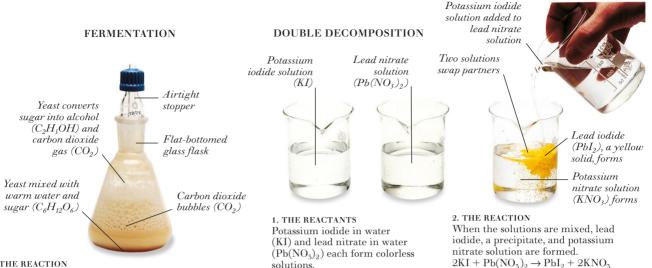
DISPLACEMENT



THE REACTION
Copper metal added to silver nitrate solution produces copper nitrate and silver metal. $Cu + 2AgNO_5 \rightarrow Cu(NO_5)_0 + 2Ag$



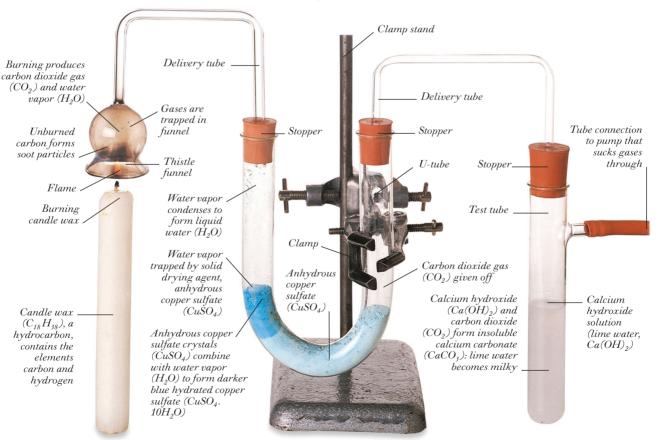
Addition of sodium hydroxide changes dichromate ions back into chromate ions. $\text{Cr}_2\text{O}_7^{2-} \to 2\text{Cr}\text{O}_4^{-2-}$



THE REACTION Yeast converts sugar and warm water into alcohol and carbon dioxide. $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

TESTING CANDLE WAX, AN ORGANIC COMPOUND

solutions.



1. THE BURNING REACTION Burning wax produces carbon dioxide gas and water vapor. $2C_{18}H_{58} + 55O_2 \rightarrow 36CO_2 + 38H_20$

2. TESTING FOR WATER VAPOR

A solid drying agent traps water vapor, proving the presence of hydrogen in the candle wax. $CuSO_4 + 10H_2O \rightarrow CuSO_4$. $10H_2O$

3. TESTING FOR CARBON DIOXIDE

Calcium hydroxide in solution reacts with carbon dioxide, forming a carbonate and turning milky. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Energy

Anything that happens—from a pin-drop to an explosion—requires energy. Energy is the capacity for "doing work" (making something happen). Various forms of energy exist, including light, heat, sound, electrical, chemical, nuclear, kinetic, and potential energies. The Law of Conservation of Energy states that the total amount of energy in the universe is fixed—energy cannot be created or destroyed. It means that energy can only change from one form to another (energy transfer). For example, potential energy is energy that is "stored," and can be used in the future. An object gains potential energy when it is lifted; as the object is released, potential energy changes into the energy of motion (kinetic energy). During transference, some of the energy converts into heat. A combined heat and power station can put some of the otherwise "waste" heat to useful effect in local schools and housing. Most of the Earth's energy is provided by the Sun, in the form of electromagnetic radiation (see pp. 316-317). Some of this energy transfers to plant and animal life, and ultimately to fossil fuels, where it is stored in chemical form. Our bodies obtain energy from the food we eat, while energy needed for other tasks, such as heating and transport, can be obtained by burning fossil fuels—or by harnessing natural forces like wind or moving water—to generate electricity. Another source is nuclear power, where energy is released by reactions in the nucleus of an atom. All energy is measured by the international unit, the joule (J). As a guide, one joule is about equal to the amount of energy needed to lift an apple one meter.

CROSS-SECTION OF NUCLEAR POWER STATION WITH

Coolant (water)

takes heat from

reactor core to

heat exchanger

Heat

exchanger

Pump

Water pumped back into

steam generator

PRESSURIZED WATER REACTOR

Steam generator.

Concrete

shielding

pressurizer

Steel girder.

framework

Control rod

Reactor core

Moderator (water)

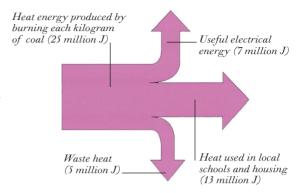
Pump

Enriched

uranium fuel

Water

SANKEY DIAGRAM SHOWING ENERGY FLOW IN A COAL-FIRED COMBINED HEAT AND POWER STATION



CROSS-SECTION OF HYDROELECTRIC POWER STATION WITH FRANCIS TURBINE

Bushing

Anna

Insulator

Transformer

Switch gear

circuit braker

including

High voltage

Rotor house

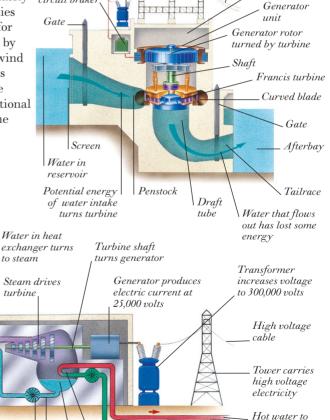
cooling tower

Cold water

from cooling

tower

cable

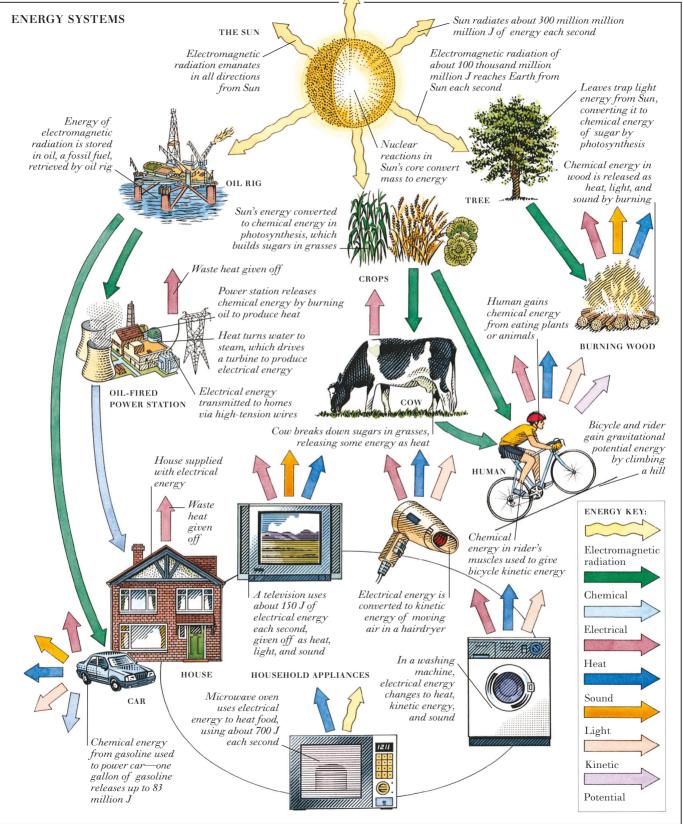


Water cools used steam

Steam loses energy to turbine

and condenses back to water

314



VAN DE GRAAFF (ELECTROSTATIC) GENERATOR

Electricity and magnetism

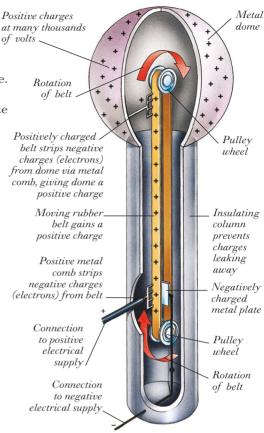
ELECTRICAL EFFECTS result from an imbalance of electric charge. There are two types of electric charge, named positive (carried by protons) and negative (carried by electrons). If charges are opposite (unlike), they attract one another, while like charges repel. Forces of attraction and repulsion (electrostatic forces) exist between any two charged particles. Matter is normally uncharged, but if

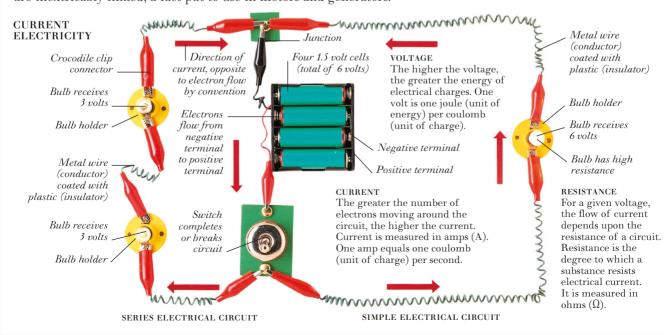


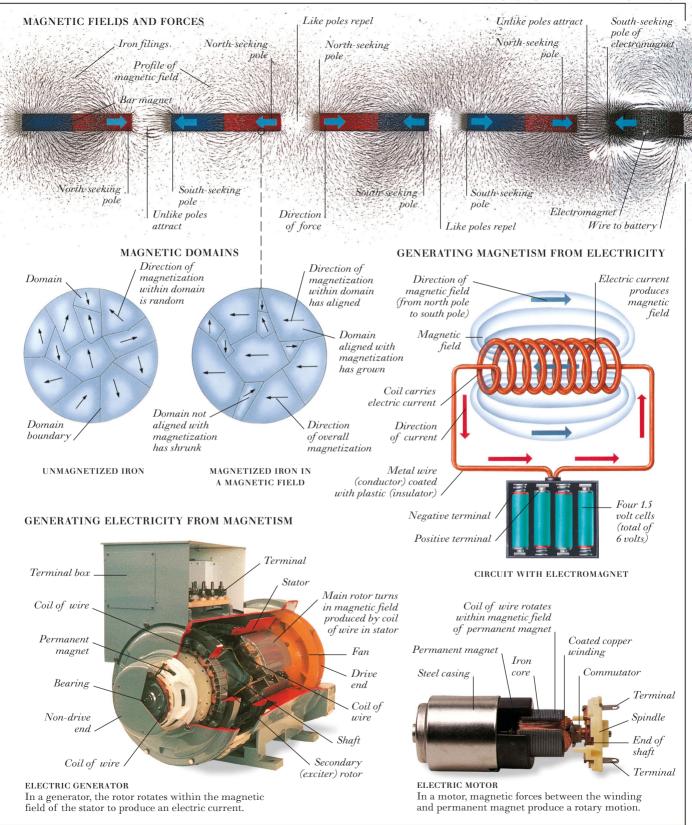
LIGHTNING

electrons are gained, an object will gain an overall negative charge; if they are removed, it becomes positive. Objects with an overall negative or positive charge are said to have an imbalance of charge, and exert the same forces as individual negative and positive charges. On this larger scale, the forces will always act to regain the balance of charge. This causes static electricity. Lightning, for example, is produced by clouds discharging a huge excess of negative electrons. If charges are "free"—in a wire or material that allows

electrons to pass through it—the forces cause a flow of charge called an electric current. Some substances exhibit the strange phenomenon of magnetism—which also produces attractive and repulsive forces. Magnetic substances consist of small regions called domains. Normally unmagnetized, they can be magnetized by being placed in a magnetic field. Magnetism and electricity are inextricably linked, a fact put to use in motors and generators.

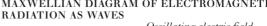








MAXWELLIAN DIAGRAM OF ELECTROMAGNETIC



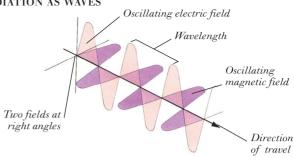


OF A HOUSE

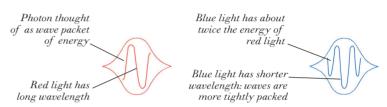
LIGHT IS A FORM OF ENERGY. It is a type of electromagnetic radiation, like Xrays or radio waves. All electromagnetic INFRARED IMAGE radiation is produced by electric charges (see pp. 316-317): it is caused by the effects

of oscillating electric and magnetic fields as they travel through space. Electromagnetic radiation is considered to have both wave and particle properties. It can be thought

of as a wave of electricity and magnetism. In that case, the difference between the various forms of radiation is their wavelength. Radiation can also be said to consist of particles, or packets of energy, called photons. The difference between light and X-rays, for instance, is the amount of energy that each photon carries. The complete range of radiation is referred to as the electromagnetic spectrum, extending from low energy, long wavelength radio waves to high energy, short wavelength gamma rays. Light is the only part of the electromagnetic spectrum that is visible. White light from the Sun is made up of all the visible wavelengths of radiation, which can be seen when it is separated by using a prism. Light, like all forms of electromagnetic radiation, can be reflected (bounced back) and refracted (bent). Different parts of the electromagnetic spectrum are produced in different ways. Sometimes visible lightand infrared radiation—is generated by the vibrating particles of warm or hot objects. The emission of light in this way is called incandescence. Light can also be produced by fluorescence, a phenomenon in which electrons gain and lose energy within atoms.



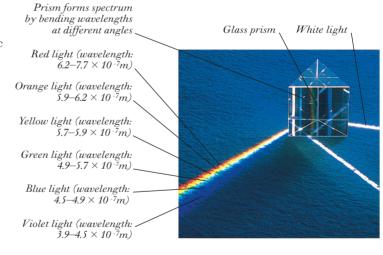
ELECTROMAGNETIC RADIATION AS PARTICLES



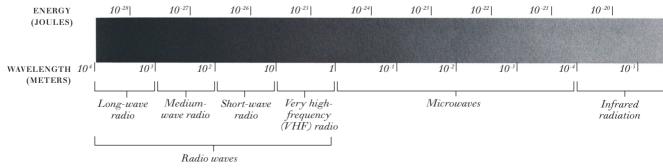
PHOTON OF RED LIGHT

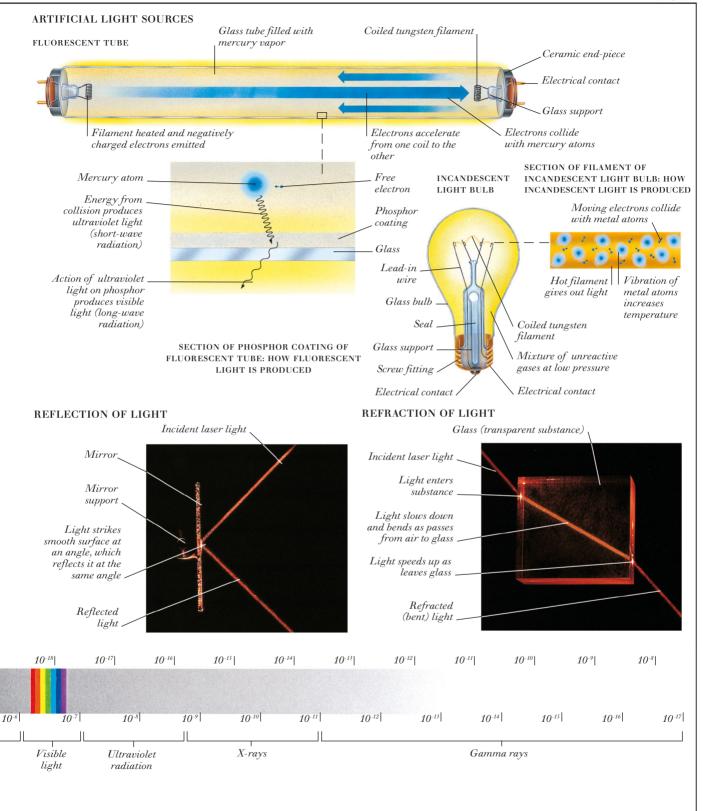
PHOTON OF BLUE LIGHT

SPLITTING WHITE LIGHT INTO THE SPECTRUM



THE ELECTROMAGNETIC SPECTRUM





Force and motion

Simple pulley only changes direction of a force

Single-pulley system

Pulley wheel -

(simple pulley)

One rope

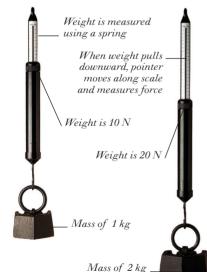
attached

FORCES ARE PUSHES OR PULLS that change the Effort is the motion of objects. To make a stationary object same size as the load (10 N) and move, or a moving object stop, a force is needed. is pulled the A force is also required to change the speed or same distance direction of an object. This change in speed or direction is known as acceleration. Acceleration depends on the size (magnitude) of the force, and on the mass of the object. The effects of forces were first summarized by

a small distance. This is called the Law of Simple Machines.

to load Load Isaac Newton in his three laws of motion. The international unit of force, named after him, is the newton (N), which is approximately equal to the weight of one apple. Gravity—the force of attraction between any two masses—can be measured using a newton meter (spring balance). Forces are put to useful effect in machines. A simple machine, such as a wheel and axle, is a device that changes the size or direction of an applied force. It allows an applied force (the effort) to produce another force (the load). A lever uses a bar that turns on a fulcrum to exert force. In all simple machines, there is a relationship between force and distance. A small force (in a compound pulley, for instance) moves through a large distance to lift a heavy object

NEWTON METERS (SPRING BALANCES)



WEIGHT AND MASS

The "mass" of an object is a measure of the quantity of matter that it possesses. Mass is usually measured in grams (g) or kilograms (kg). The "weight" of an object is the force exerted on the object's mass by gravity. Since weight is a force, its unit is the newton (N).

Wheel and axle multiplies the effort

Force is transmitted to the wheels by the chain

Effort, a A screw, acting like turning force a wedge wrapped supplied around a shaft, through a multiplies the effort

SCREW

The smaller the angle of pitch, the less force is required, but more turns are needed to move

it through a

greater distance

screwdriver Pitch (the angle of the screw

WHEEL AND AXLE

A larger force, the load, pulls the screw into wood

thread)

SIMPLE MACHINES Two-pulley system

(simple pulley) Pulley wheel.

Effort is half the load (5 N), but the rope must be pulled twice the distance

Two ropes share the force and distance

Pulley wheel

Load of 10 N.

Four-pulley system (compound pulley) _

Two pulley. wheels

> Effort is one quarter of the load (ž.5 N), but the rope must be pulled four times the distance

Four ropes share the force and distance

SIMPLE AND COMPOUND PULLEYS

Twopulley wheels

Load of 10 N

Effort, provided by cyclist's muscles, is smaller than the load, but moves through a greater distance

4 larger force, the load, is producedat the axle

Crank

Effort pushes ax into wood

A larger force, the load, moves through a smaller distance to push wood apart Ax blade has wedge shape

Wedge multiplies effort

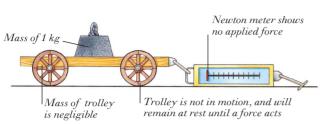
WEDGE

NEWTON'S THREE LAWS OF MOTION

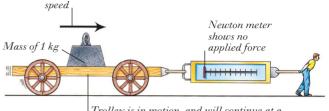
Constant



When no force acts on a body, it will continue in a state of rest or uniform motion.



NO FORCE, NO ACCELERATION: STATE OF REST

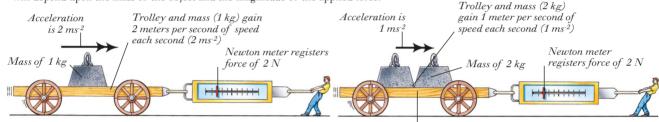


Trolley is in motion, and will continue at a constant speed in a straight line until a force acts

NO FORCE, NO ACCELERATION: UNIFORM MOTION

NEWTON'S SECOND LAW

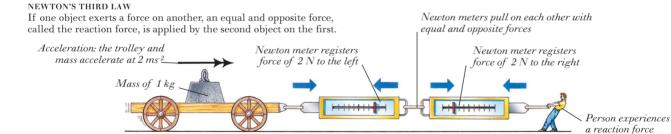
When a force acts on a body, the motion of the body will change. The size of the change will depend upon the mass of the object and the magnitude of the applied force.



With the same applied force, an object with 2 kg mass accelerates at half the rate of object with 1 kg mass

FORCE AND ACCELERATION: SMALL MASS, LARGE ACCELERATION

FORCE AND ACCELERATION: LARGE MASS, SMALL ACCELERATION



ACTION AND REACTION



321





Rail and Road

STEAM LOCOMOTIVES	324
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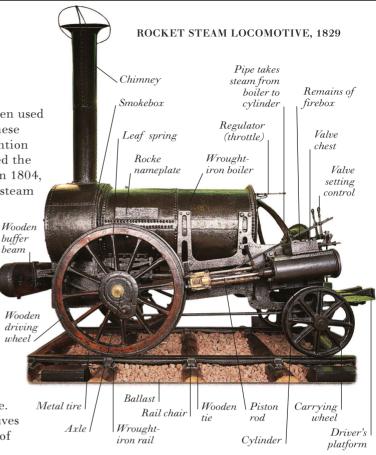


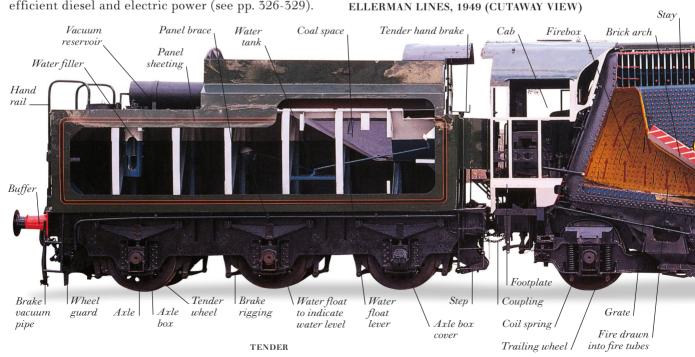
Steam locomotives

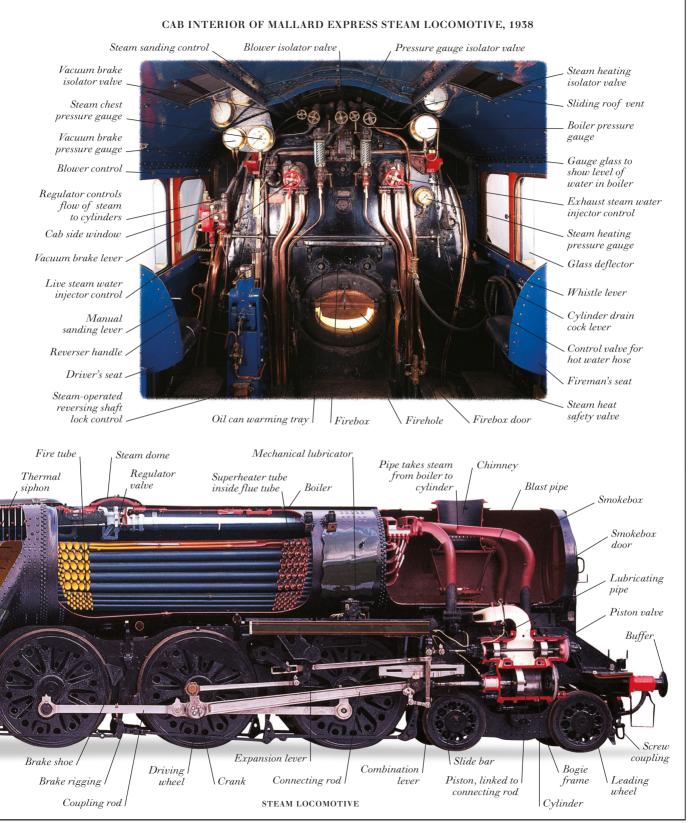
WAGONS THAT ARE PULLED along tracks have been used to transport material since the 16th century, but these trains were drawn by men or horses until the invention of the steam locomotive. Steam locomotives enabled the basic railroad system to realize its true potential. In 1804, Richard Trevithick built the world's first working steam locomotive in South Wales. It was not entirely successful, but it encouraged others to develop new designs. By 1829, the British engineer

Wooden buffer

successful, but it encouraged others to develop new designs. By 1829, the British engineer Robert Stephenson had built the Rocket, considered to be the forerunner of the modern locomotive. The Rocket was a self-sufficient unit, carrying coal to heat the boiler and a water supply for generating steam. Steam passed from the boiler to force the pistons back and forth, and this movement turned the driving wheels, propelling the train forward. Used steam was then expelled in characteristic puffs. Later steam locomotives, like Ellerman Lines and the Mallard, worked in a similar way, but on a much larger scale. The simple design and reliability of steam locomotives ensured that they changed very little in 120 years of use, before being replaced from the 1950s by more efficient diesel and electric power (see pp. 326-329).



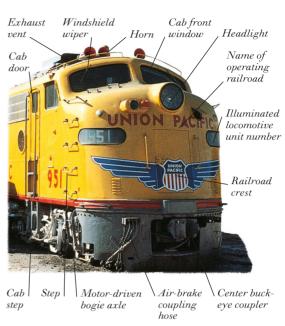




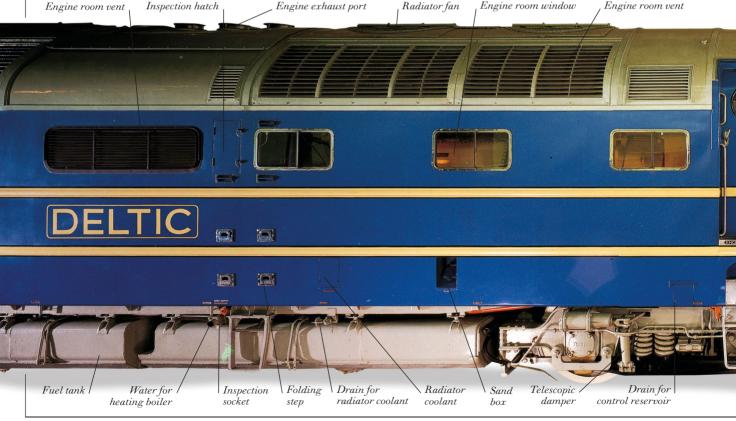
Diesel trains

RUDOLF DIESEL FIRST DEMONSTRATED the diesel engine in Germany in 1898, but it was not until the 1940s that diesel locomotives were successfully established on both passenger and freight services in the US. Early diesel locomotives like the Union Pacific were more expensive to build than steam locomotives, but were more efficient and cheaper to operate, especially where oil was plentiful. One feature of diesel engines is that the power output cannot be coupled directly to the wheels. To convert the mechanical energy produced by diesel engines. a transmission system is needed. Almost all diesel locomotives have electric transmissions, and are known as diesel-electric locomotives. The diesel engine works by drawing air into the cylinders and compressing it to increase its temperature; a small quantity of diesel fuel is then injected into it. The resulting combustion drives the generator (more recently an alternator) to produce electricity, which is fed to electric motors connected to the wheels. Diesel-electric locomotives are essentially electric locomotives that carry their own power plants, and are used worldwide today. The Deltic diesel-electric locomotive, similar to the one shown here, replaced classic express steam locomotives, and ran at speeds up to 100 mph (160 kph).

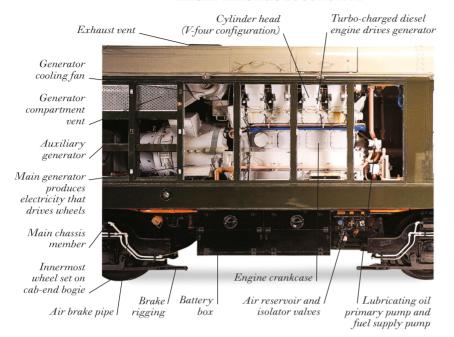
FRONT VIEW OF UNION PACIFIC DIESEL-ELECTRIC LOCOMOTIVE, 1950s



PROTOTYPE DELTIC DIESEL-ELECTRIC LOCOMOTIVE, 1956



DIESEL ENGINE OF BRITISH RAIL CLASS 20 DIESEL-ELECTRIC LOCOMOTIVE



EXAMPLES OF FREIGHT CARS



BOX CAR



HOPPER CAR



REFRIGERATOR CAR



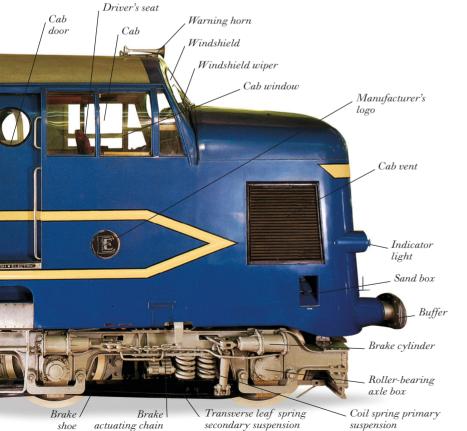
LIVESTOCK CAR



FLAT CAR WITH BULKHEADS



AUTOMOBILE CAR



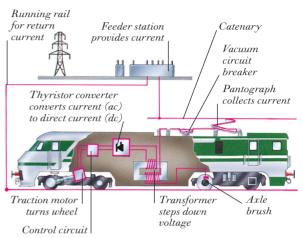
Electric and high-speed trains

THE FIRST ELECTRIC LOCOMOTIVE ran in 1879 in Berlin. Germany. In Europe, electric trains developed as a more efficient alternative to the steam locomotive and dieselelectric power. Like diesels, electric trains employ electric motors to drive the wheels but, unlike diesels, the electricity is generated externally at a power station. Electric current is picked up either from a catenary (overhead cable) via a pantograph, or from a third rail. Since it does not carry its own power-generating equipment, an electric locomotive has a better power-to-weight ratio and greater acceleration than its dieselelectric equivalent. This makes electric trains suitable for urban routes with many stops. They are also faster, quieter, and cause less pollution. The latest electric French TGV (Train à Grande Vitesse) reaches 185 mph (300 kph); other trains, like the London to Paris and Brussels Eurostar, can run at several voltages and operate between different countries. Simpler electric trains perform special duties—the "People Mover" at Gatwick Airport in London runs between terminals.

FRONT VIEW OF PARIS METRO



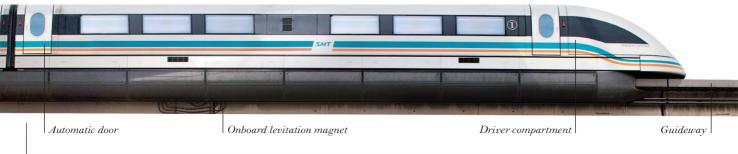
HOW ALTERNATING CURRENT (AC) ELECTRIC TRAINS WORK

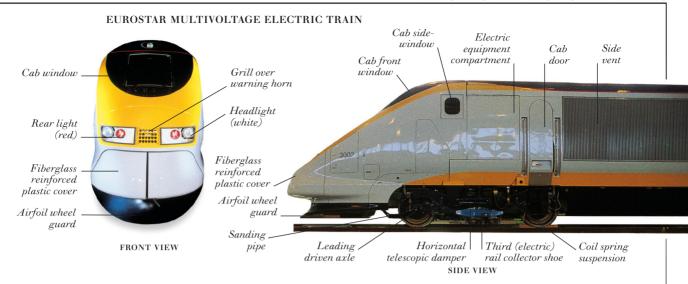


FRONT VIEW OF ITALIAN STATE RAILROADS CLASS 402 ELECTRIC LOCOMOTIVE

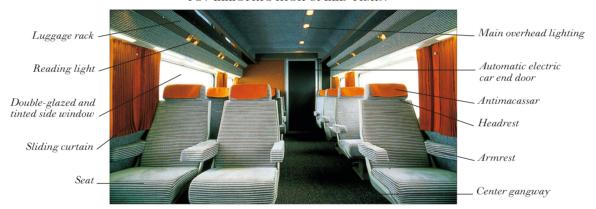


SIDE VIEW OF SHANGHAI MAGLEV TRAIN

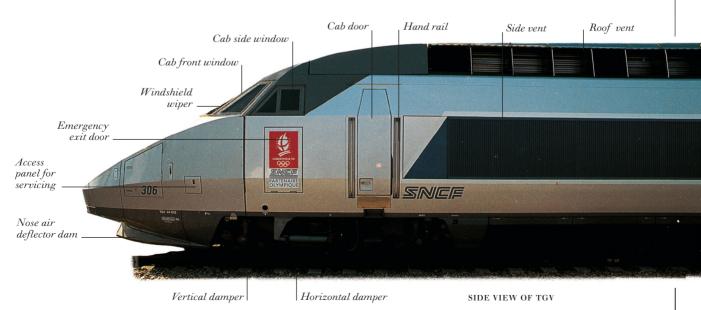


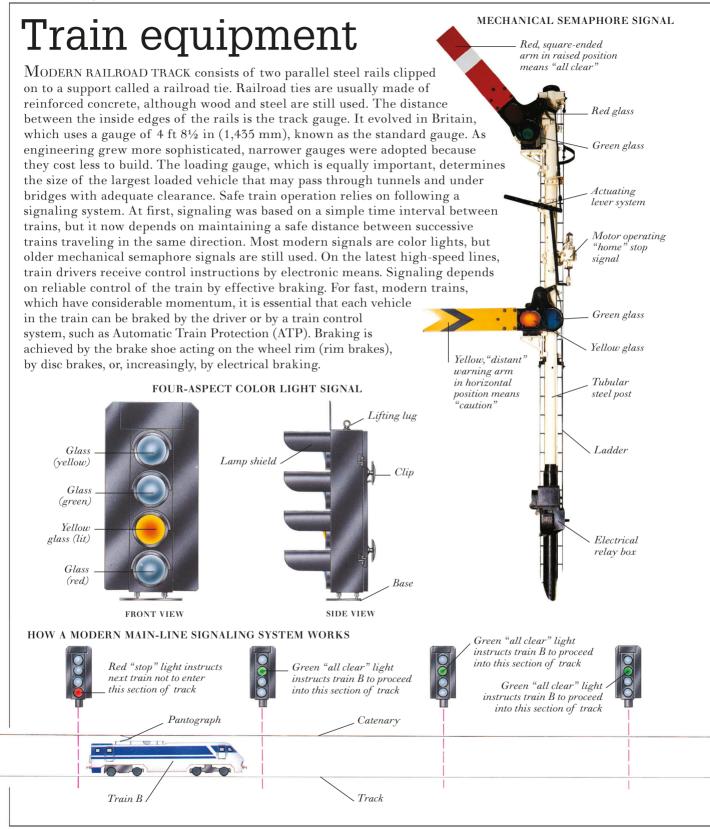


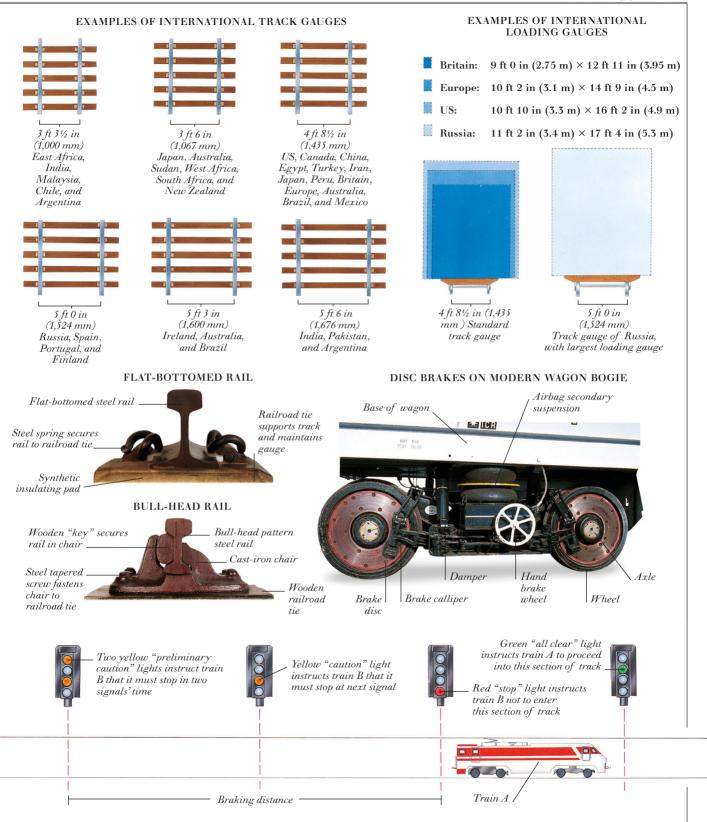
TGV ELECTRIC HIGH-SPEED TRAIN



INTERIOR OF TGV







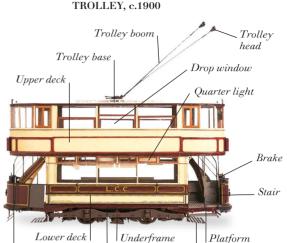
Trolleys and buses



METROLINK TROLLEY,

As city populations exploded in the 1800s, there was an urgent need for mass transportation. Trolleys were an early solution. The first trolleys, like buses, were horse-drawn, but in 1881, electric streetcars appeared in Berlin, Germany. Electric streetcars soon became widespread throughout Europe and North America. Trolleys run on rails along a fixed route, using electric motors that receive power from overhead cables. As road networks

MANCHESTER, UK from overhead cables. As road networks developed, motorized buses offered a flexible alternative to trolleys. By the 1930s, they had replaced trolley systems in many cities. City buses typically have doors at both front and rear to make loading and unloading easier. Double-decker designs are popular, occupying the same amount of street space as single-decker buses but able to transport twice the number of people. Buses are also commonly used for intercity travel and touring. Tour buses have reclining seats, large windows, luggage space, and toilets. Recently, as city traffic has become increasingly congested, many city planners have designed new electric streetcar routes to run alongside bus routes as part of an integrated transportation system.

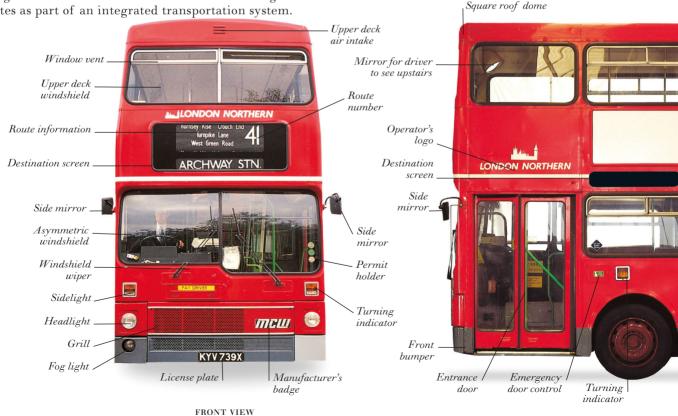


MCW METROBUS, LONDON, UK

Truck

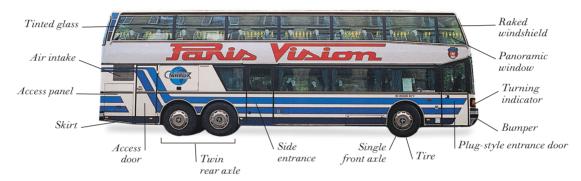
Controller

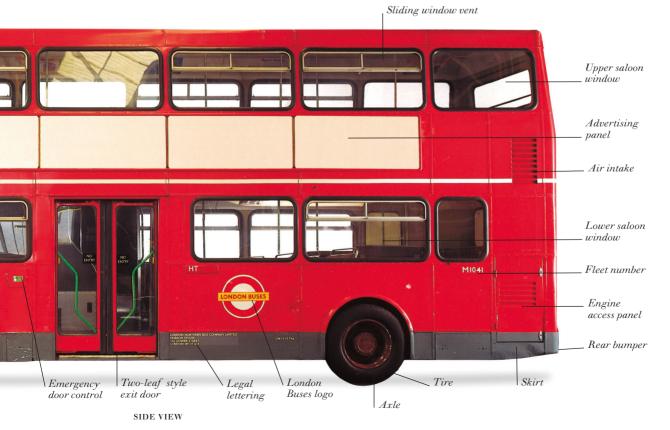
Lifeguard

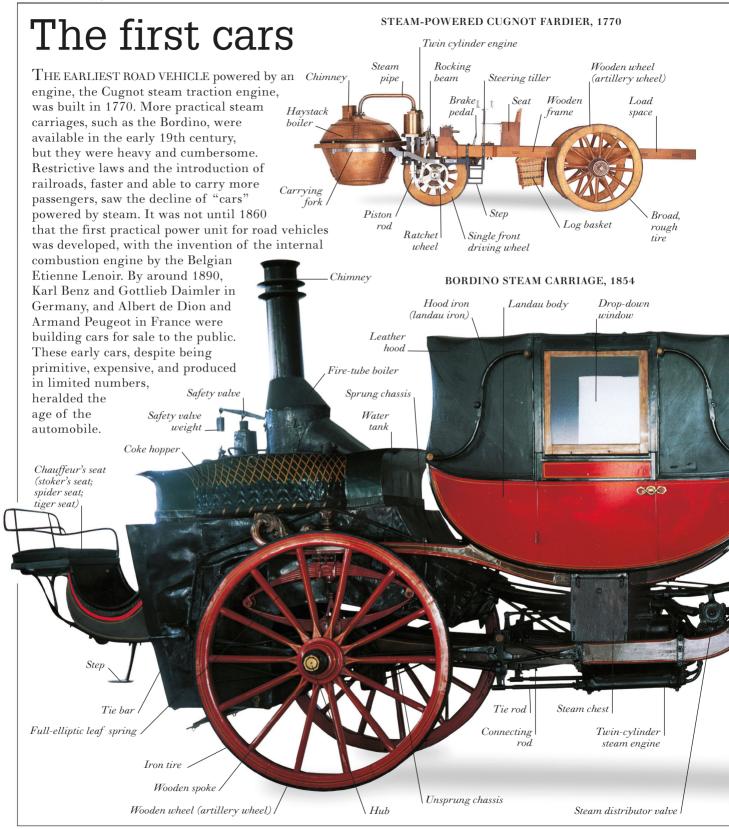


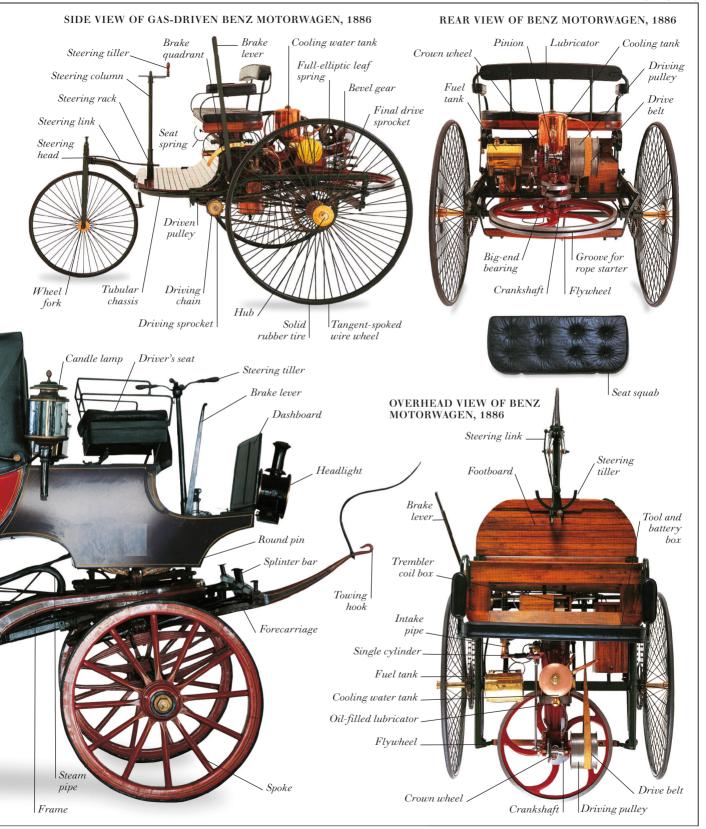
SINGLE-DECKER BUS, NEW YORK CITY Wheelchair access Sliding window Sloped roof dome Marker light Repeater indicator EntrancedoorSide Tinted mirrorglass Route number Headlight Bumper **Turning** indicator Exit License plate Entrance Air intake Access panel door Bumper Sidelight TiredoorSIDE VIEW FRONT VIEW

DOUBLE-DECKER TOUR BUS, PARIS, FRANCE



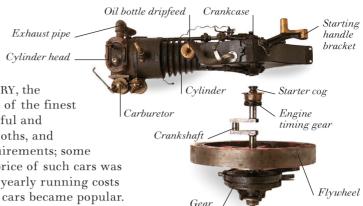






Elegance and utility

1904 OLDSMOBILE SINGLE-CYLINDER ENGINE

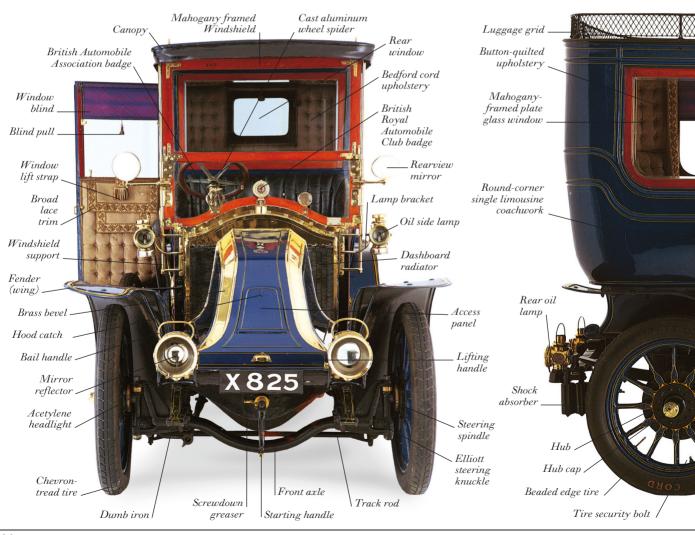


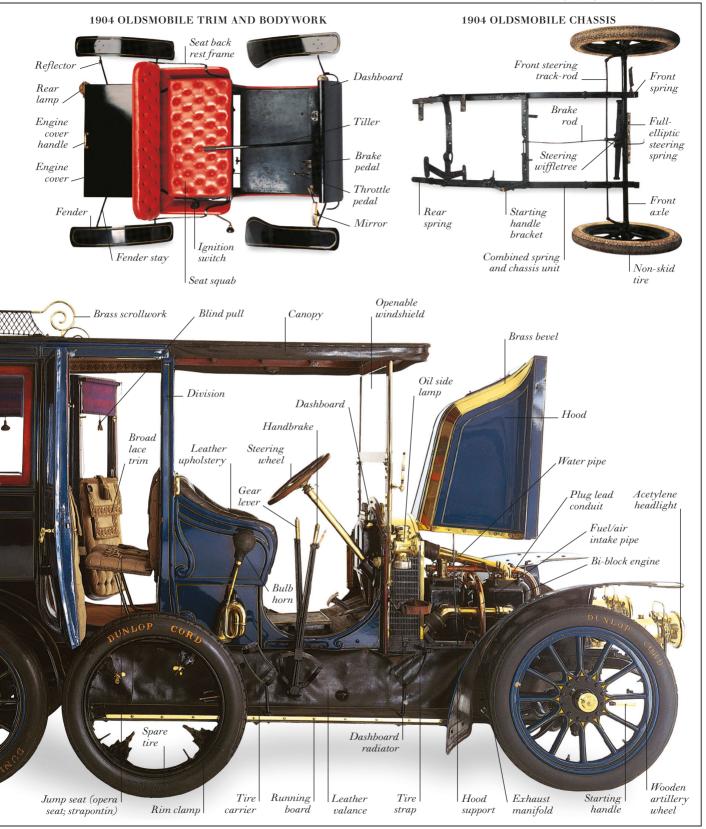
hand.

DURING THE FIRST DECADE OF THE 20TH CENTURY, the motorist who could afford it had a choice of some of the finest cars ever made. These handbuilt cars were powerful and luxurious, using the finest woods, leathers, and cloths, and bodywork made to the customer's individual requirements; some had six-cylinder engines as big as 15 liters. The price of such cars was several times that of an average house, and their yearly running costs were also very high. As a result, basic, utilitarian cars became popular. Costing perhaps one-tenth of the price of a luxury car, these cars had very little trim and often had only single-cylinder engines.

FRONT VIEW OF 1906 RENAULT

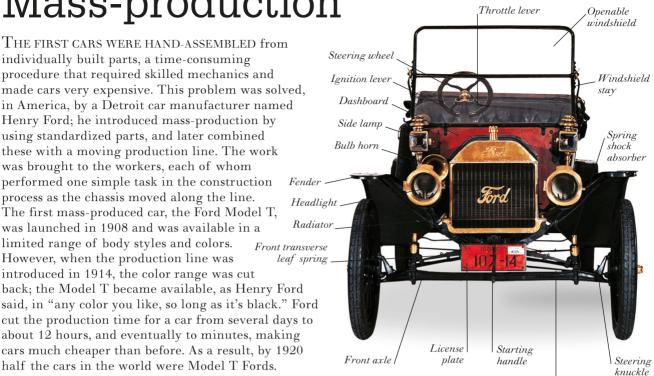
SIDE VIEW OF 1906 RENAULT





Mass-production

THE FIRST CARS WERE HAND-ASSEMBLED from individually built parts, a time-consuming procedure that required skilled mechanics and made cars very expensive. This problem was solved, in America, by a Detroit car manufacturer named Henry Ford; he introduced mass-production by using standardized parts, and later combined these with a moving production line. The work was brought to the workers, each of whom performed one simple task in the construction process as the chassis moved along the line. The first mass-produced car, the Ford Model T. was launched in 1908 and was available in a limited range of body styles and colors. However, when the production line was introduced in 1914, the color range was cut back; the Model T became available, as Henry Ford said, in "any color you like, so long as it's black." Ford cut the production time for a car from several days to about 12 hours, and eventually to minutes, making

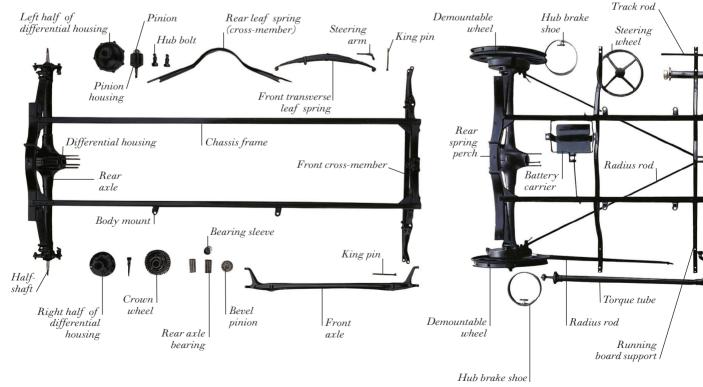


Steering spindle connecting-rod

FRONT VIEW OF 1913 FORD MODEL T

STAGES OF FORD MODEL T PRODUCTION

half the cars in the world were Model T Fords.



MASS-PRODUCTION SIDE VIEW OF 1913 FORD MODEL T Rear HoodSteering seat Hood column Windshield frame Front Steering wheel seat Rear Side lamp Horn Radiator filler cap door bulb HoodRadiatorfiller neck Front fender Rear fender Spring (rear wing) shock absorber $Tire\ valve$ Drain plug | Horn Wooden-spoked wheel. Running board SpareDummy Radius rod Hub cap Radiator shell tire front door Valance Starter HeadlightFuelSteering Running board switchrim sediment Bun lamp Light column bracket Demountable switch burnerbowlHeadlight wheel Drag link Handbrake Ruckstell axle HoodSteering Trackclipgearbox Radiator Rear cross-Brake Starter hose member drum Drop arm Drag link

Torque

tube

Battery

strap

Greaser

Tank

support?

Reflector

Headlight

shell

Running

board

Brake

rod

Front wing stay

Crank

handle

Cylinder

Radiator

Demountable wheel

Steering

Running board

arm

support

apron

Clincher

wheel

rim

Detachable

block

Transmission

casing

Radiator

Handbrake

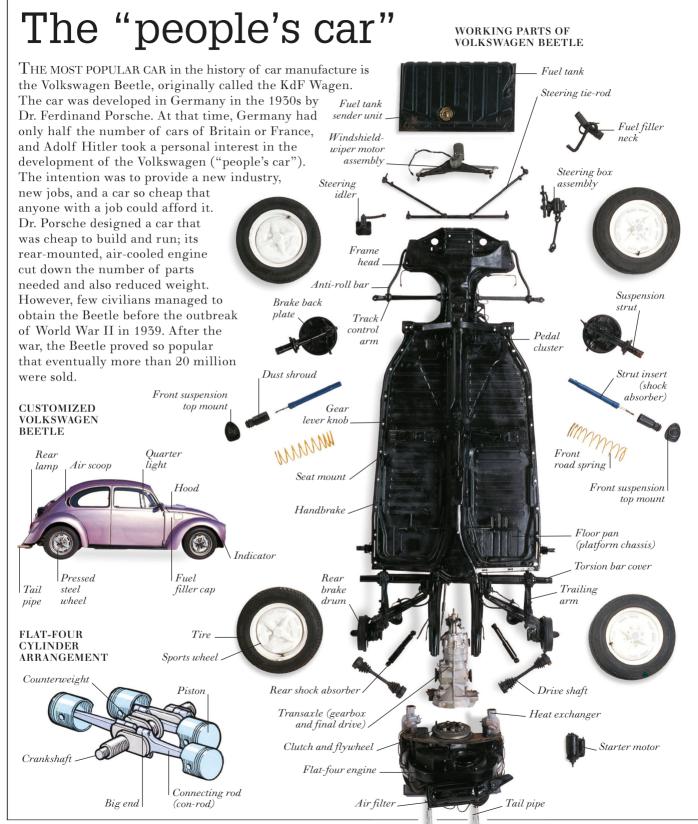
quadrant

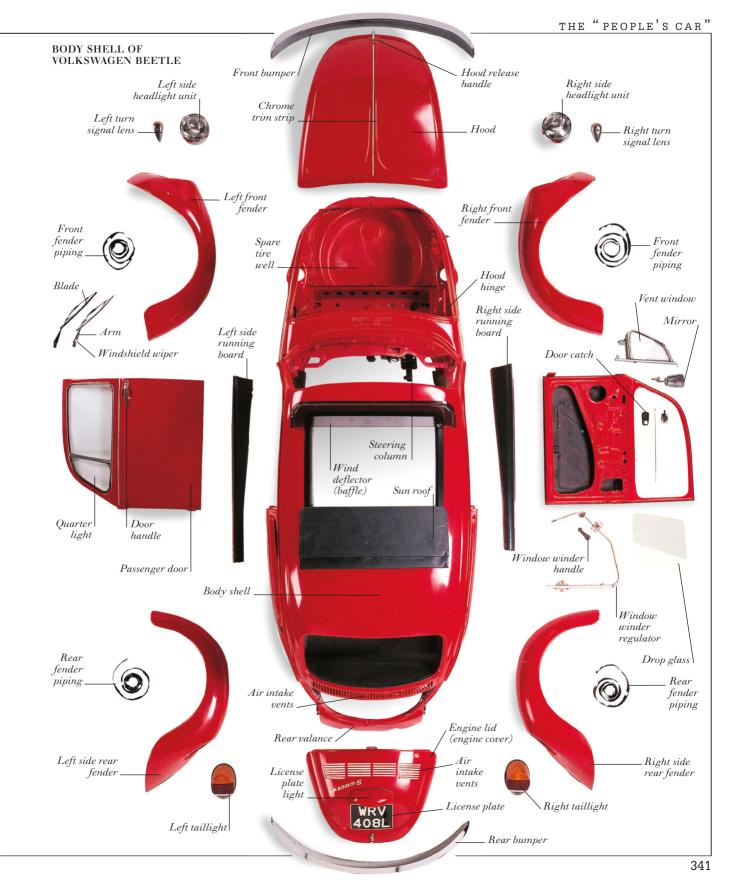
Carburetor

Hood clip

Fender

eye bolt





Early engines

STEAM AND ELECTRICITY were used to power cars until early this century, but neither power source was ideal. Electric cars had to stop frequently to recharge their heavy batteries, and steam cars gave smooth power delivery but were too complicated for the average driver to use. A rival power source, the internal combustion engine, was invented in 1860 by Etienne Lenoir (see pp. 334-335). This engine converted the force of a controlled explosion into rotary motion, to turn the wheels of a vehicle. Early variations on this basic model included sleeve valves,

separately cast cylinders, and the two-stroke combustion

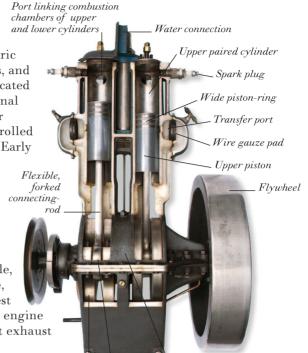
BERSEY ELECTRIC CAB, 1896

Mountine

for tray of 40 batteries cycle. Today, many internal combustion engines, including the Wankel rotary and diesels (see pp. 346-347), use the four-stroke cycle, first demonstrated by Nikolaus Otto in 1876. The Otto cycle, often described as "suck, squeeze,

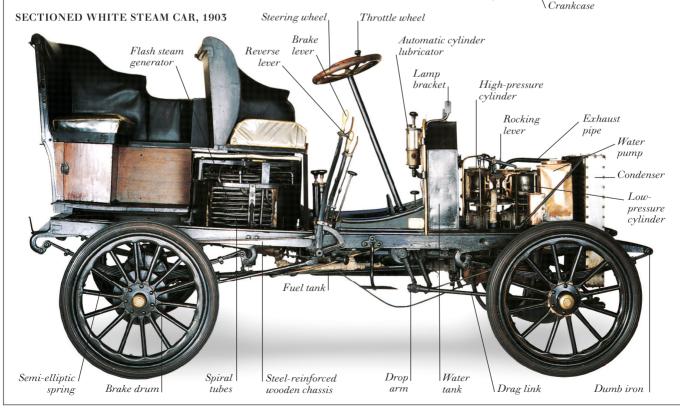
bang, blow," has proved the best method of ensuring that the engine turns over smoothly and that exhaust emissions are controllable.

Housing for electric motors

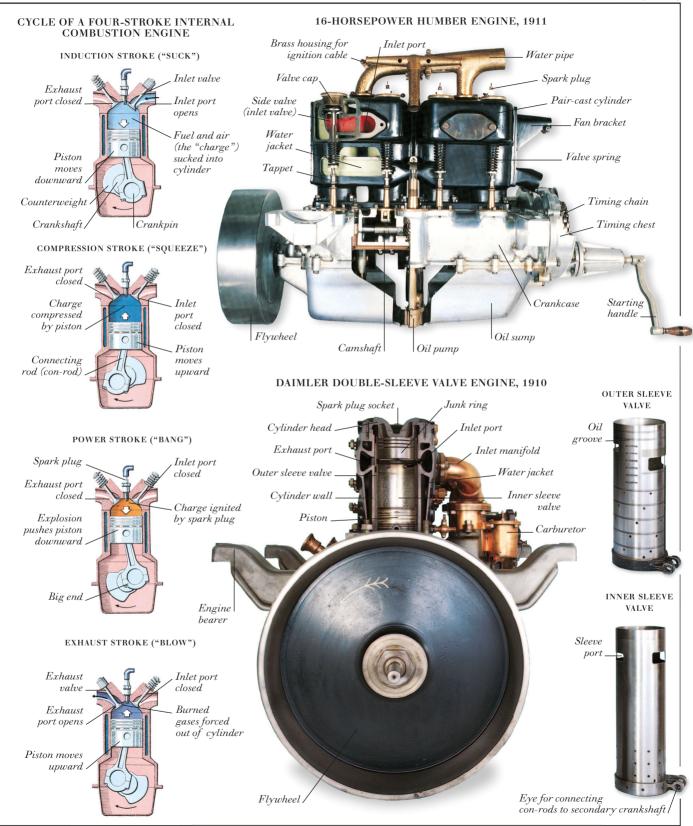


Big end

TROJAN TWO-STROKE ENGINE, 1927



Counterweight



Modern engines

TODAY'S GASOLINE ENGINE WORKS on the same basic principles as the first car engines of a century ago, although it has been greatly refined. Modern engines, often made from special metal alloys, are much lighter than earlier engines. Computerized ignition systems, fuel injectors, and multivalve cylinder heads achieve a more efficient combustion of the fuel/air mixture (the charge) so that less fuel is wasted. As a result of this greater efficiency, the power and performance of a modern engine are increased, and the level of pollution in the exhaust gases is reduced. Exhaust pollution levels today are also lowered by the increasing use of special filters called catalytic converters, which absorb many exhaust pollutants. The need to produce ever more efficient engines means that it can take up to seven years to develop a new engine for a family car, at a cost of many millions of dollars.

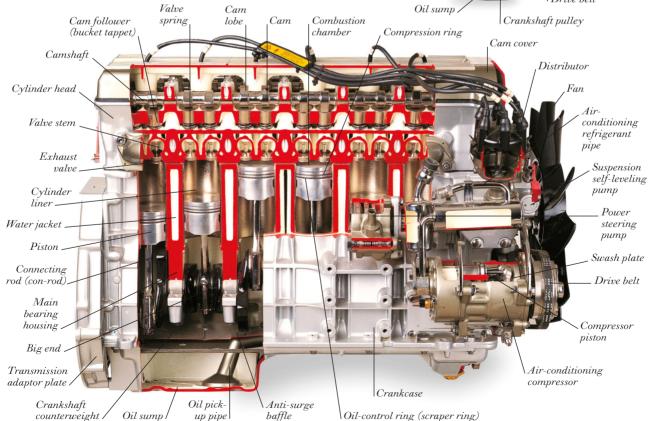
Plenum chamber Idle control valve Valve rocker Oil dipstick Power steering pump reservoir High-tension Steering pump ignition lead pulley (spark plug lead) Cogged drive belt Alternato Crankshaft pulley Viscous coupling Oil sump

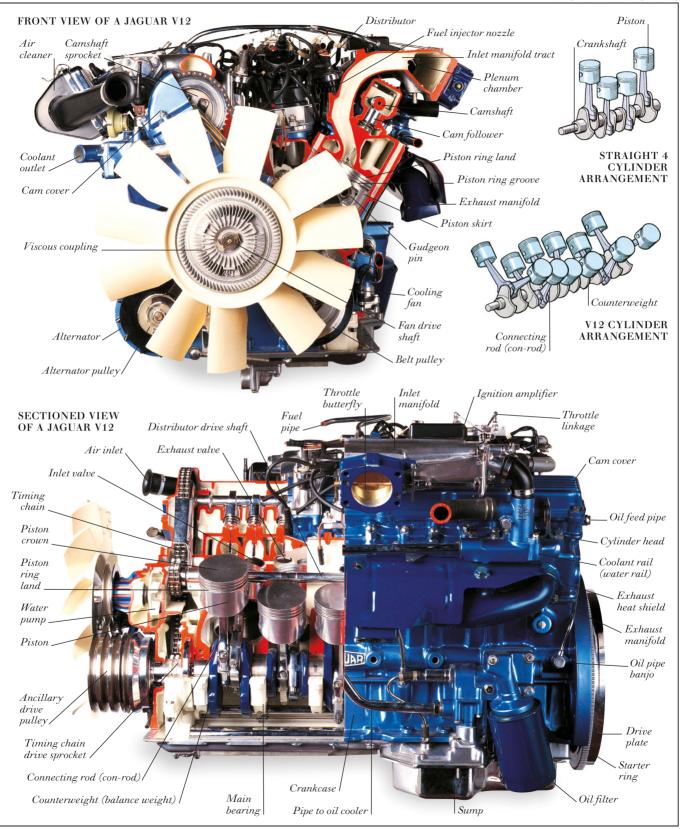
FRONT VIEW OF A FORD COSWORTH V6 12-VALVE

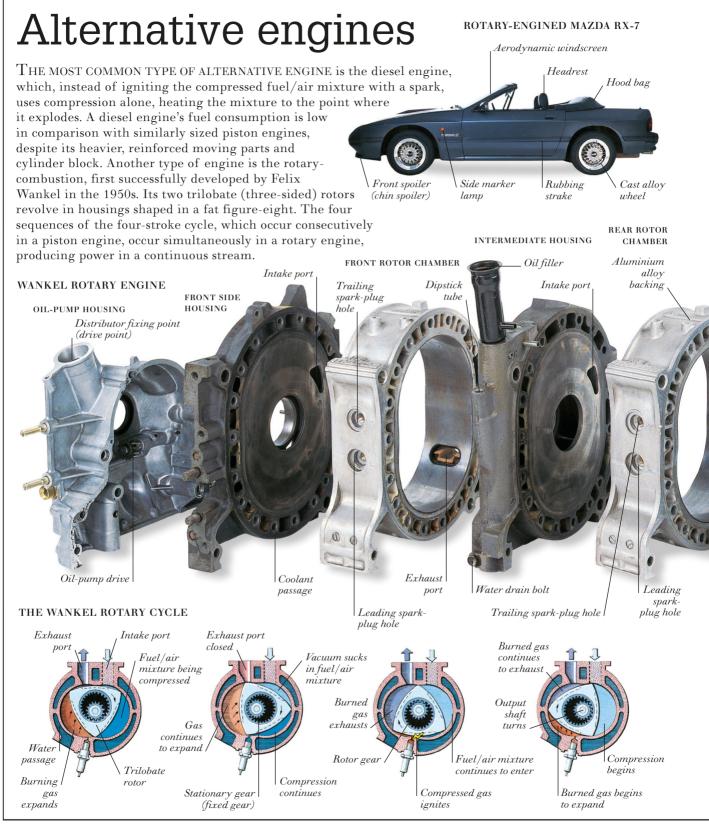
FRONT VIEW OF A FORD COSWORTH V6 24-VALVE

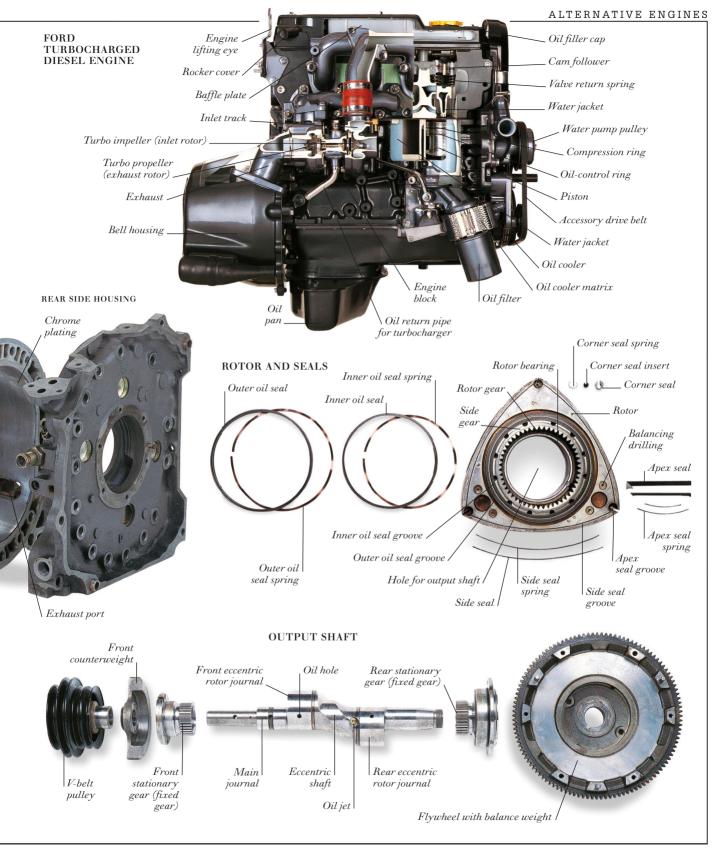


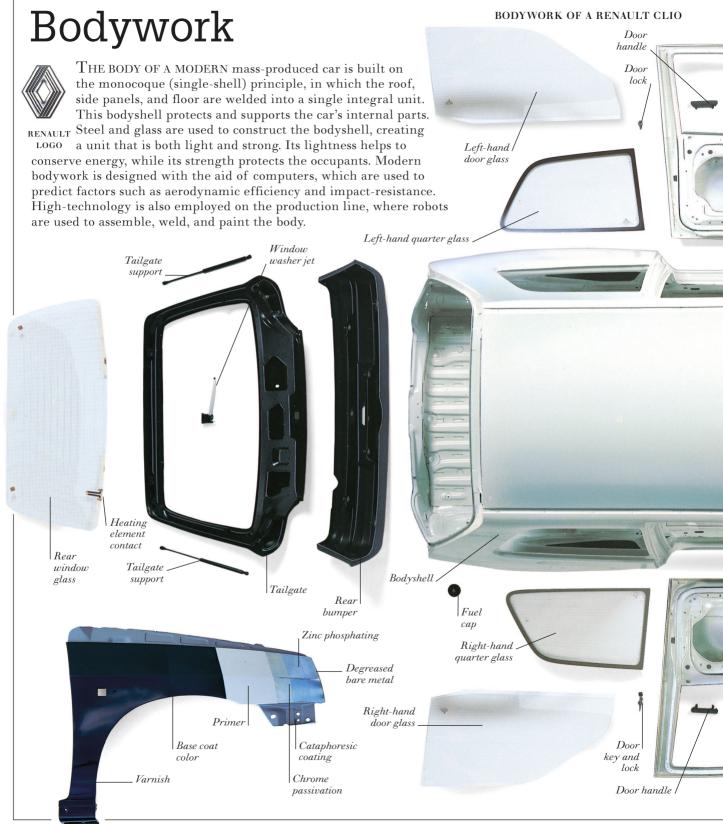
SECTIONED VIEW OF A JAGUAR STRAIGHT 6



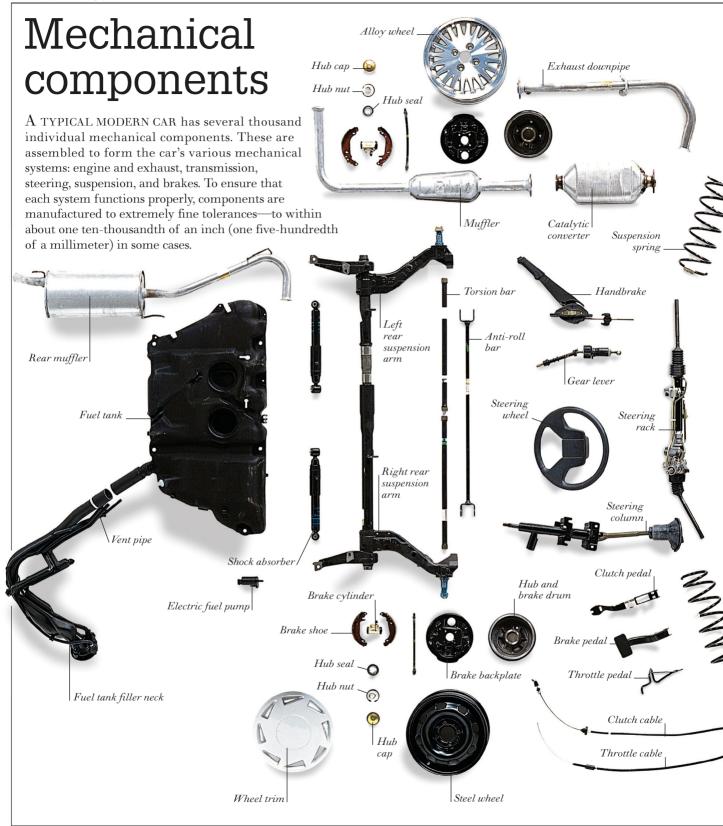


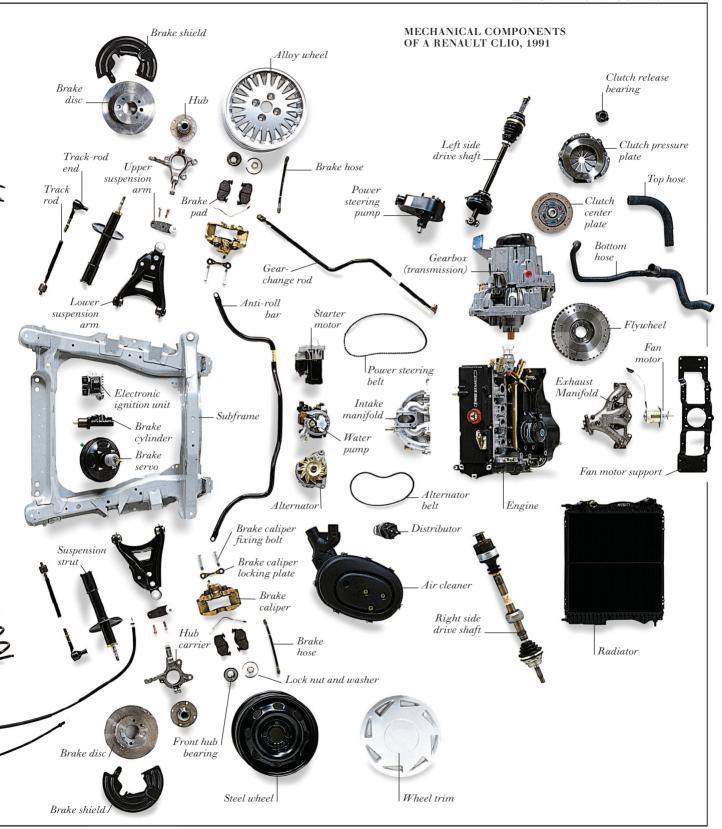




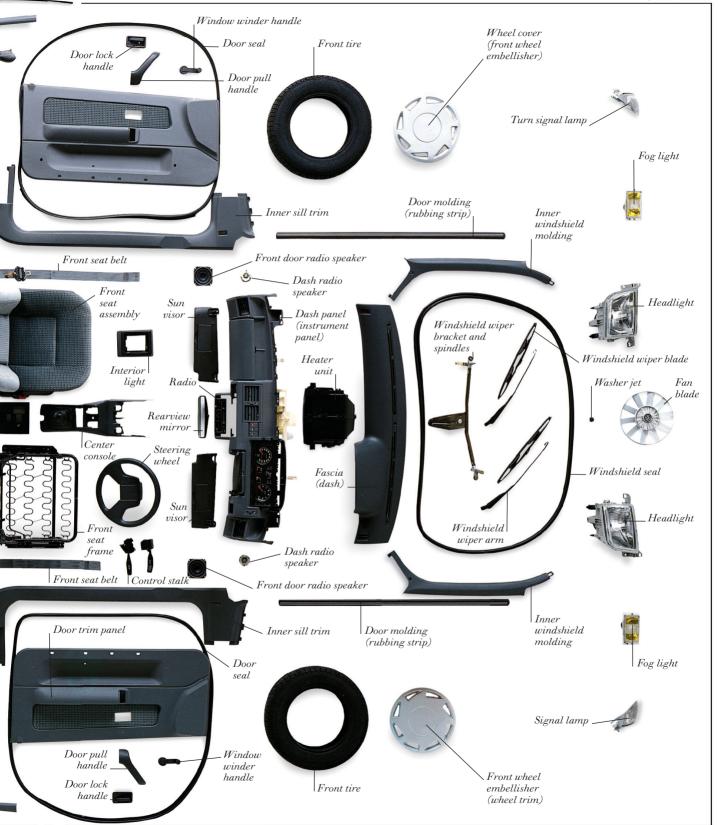






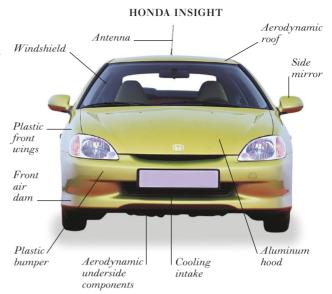


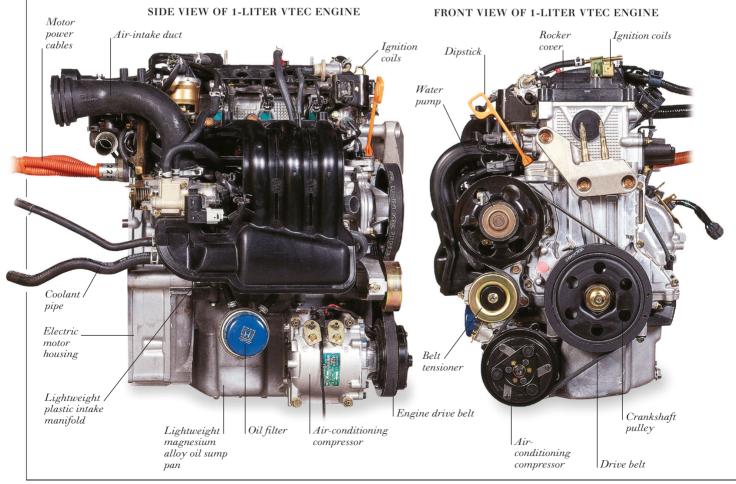


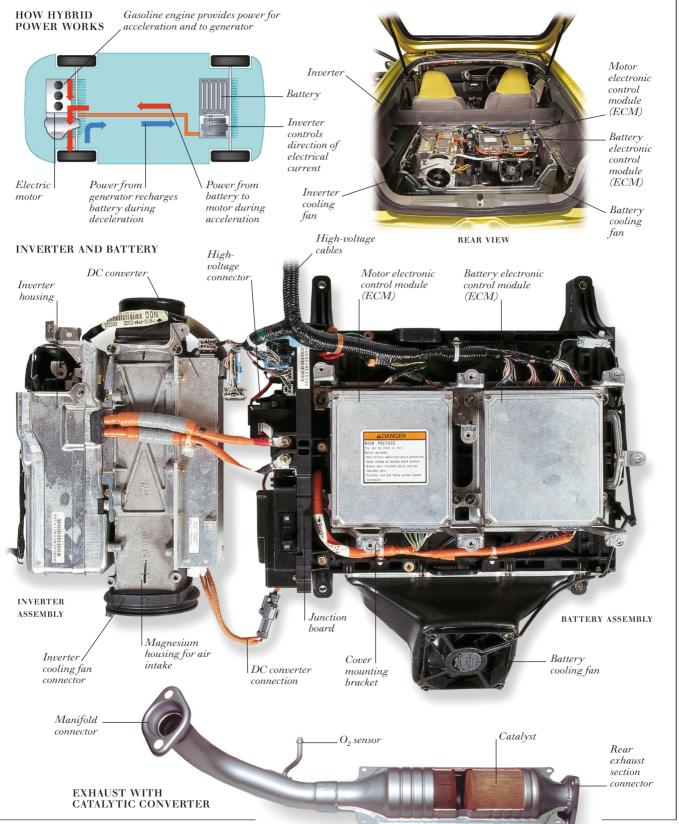


Hybrid car

THERE HAVE BEEN SEVERAL proposed alternatives to conventional gas- or diesel-powered cars, including cars that use solar or battery power. The object is to lower harmful emissions and conserve natural resources. One of the alternatives already in production is the hybrid car. A hybrid vehicle uses two or more fuels. Examples include diesel-electric trains and mopeds. The latter combine the power of a gasoline engine with pedal power. In a hybrid car, gas consumption is reduced by the provision of additional power by an electric motor during acceleration. The motor is driven by power from on-board batteries that are recharged by an enginedriven generator when the car is decelerating or cruising. Some hybrid cars transfer energy from the wheels to a flywheel during braking. The flywheel drives the generator, which recharges the batteries.



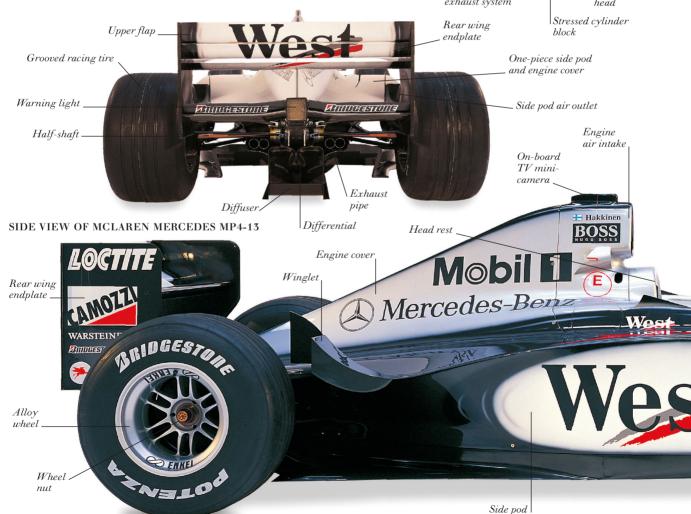


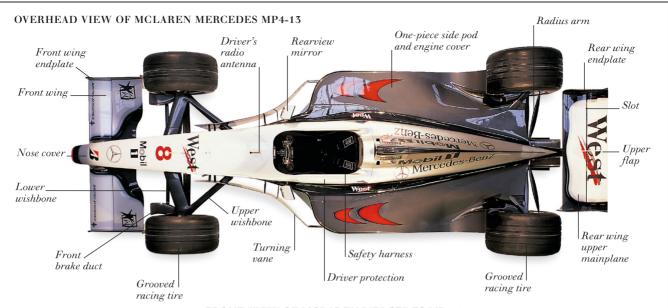


Race cars

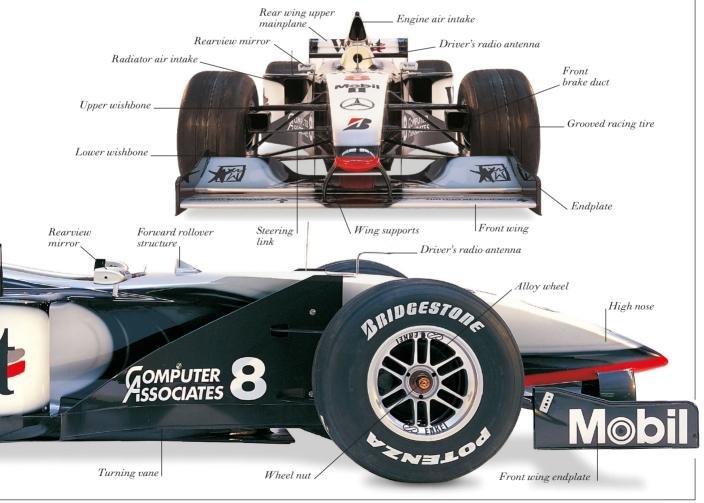
SINCE THE ADVENT OF DRIVING, race cars have been a major focus of innovation in car design. Features that are now commonplace, such as disc brakes, turbochargers, and even safety belts, were used first on competition cars. Research into race cars has contributed to a new understanding of engine performance, aerodynamics, and tire adhesion, and has led to the development of ultralight materials such as carbon fiber for car bodies. A modern McLaren Formula One car has a low, streamlined body and an open cockpit but, unlike its forerunner, it also has front and rear wings that push the wheels firmly on to the track, huge tires for extra grip, and electronic sensors that continually relay information to the pits about the car's performance.

72° V10 ENGINE Fuel injection CamGearbox trumpet guard cover fixing stud Water and oil pump assembly Harmonically tuned Cylinder BACK VIEW OF MCLAREN MERCEDES MP4-13 exhaust system head Stressed cylinder Rear wing blockendplate One-piece side pod and engine cover Side pod air outlet



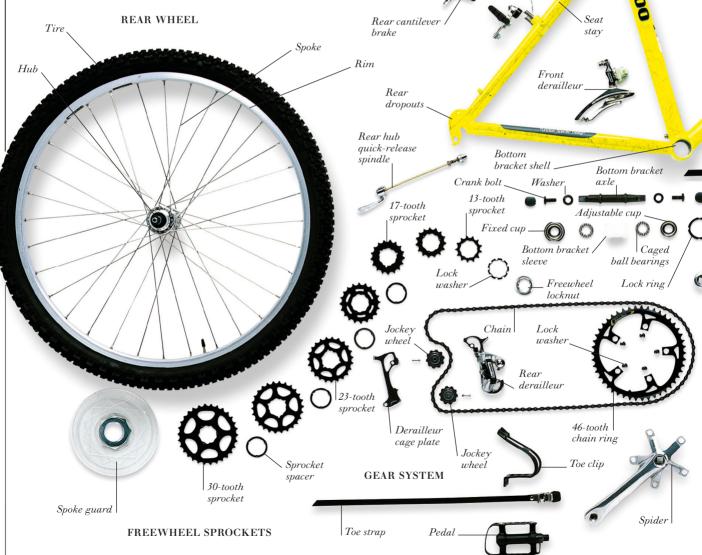


FRONT VIEW OF MCLAREN MERCEDES MP4-13



Bicycle anatomy

The bicycle is a two-wheeled, light-weight machine, which is propelled by human power. It is efficient, cheap, easily manufactured, and one of the world's most popular forms of transportation. The first pedal-driven bicycle was built in Scotland in 1839. Since then the basic design—of a frame, wheels, brakes, handlebars, and saddle—has been gradually improved, with the addition of a chain, gear system, and pneumatic tires (tires inflated with air). The recent invention of the mountain bike (all-terrain bike) has been an important development. With its strong, rugged frame, wide tires, and 21 gears, a mountain bike enables riders to reach rough and hilly areas that were previously inaccessible to cyclists.



Saddle

Cable

guide

Seat tube

Seat post

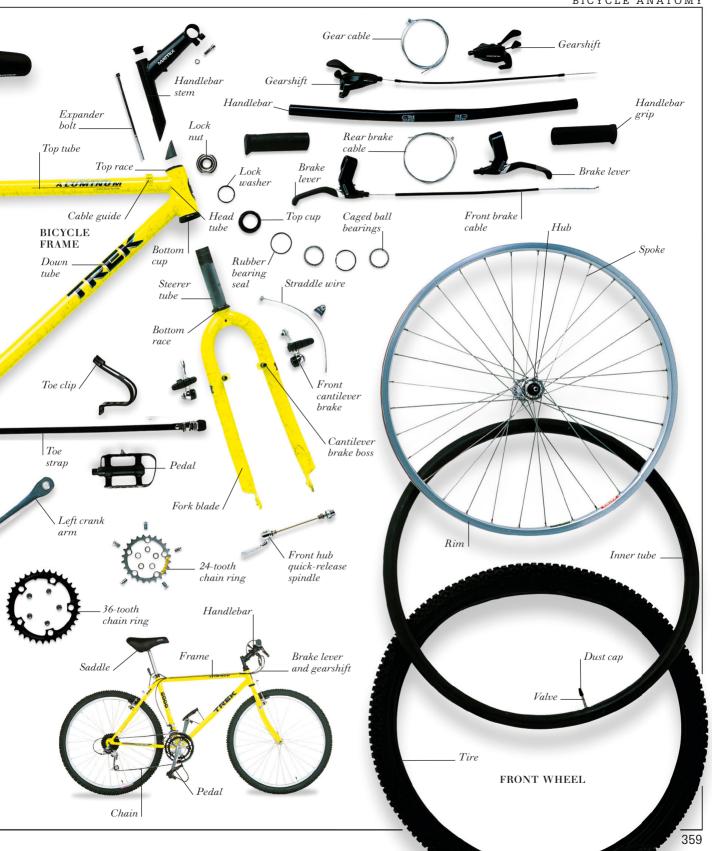
Seat post

bolt

Straddle

wire

quick-release



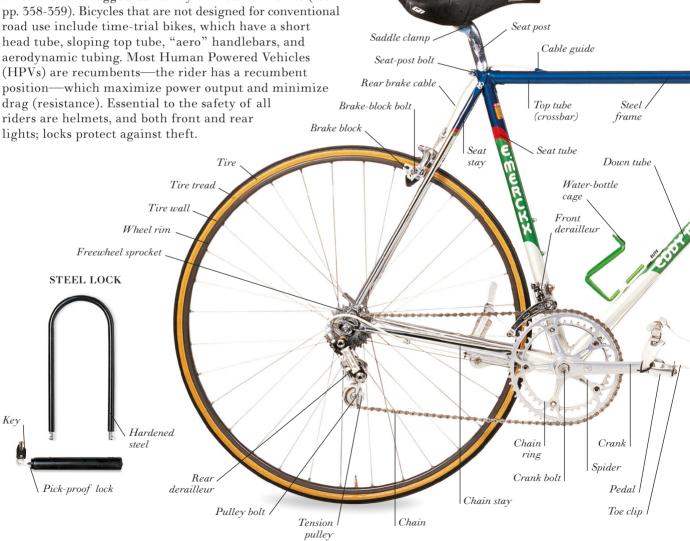
Bicycles

ALTHOUGH ALL BICYCLES are made up of the same basic components, they can vary greatly in design. A racing bike, such as the Eddy Merckx model, with its light frame and steep head- and seat-angles, is built for speed. Its design forces the rider to adopt the "aerotuck," a crouched, aerodynamic position. While a touring bike resembles the racing bike in many respects, it is designed for comfort and stability on long-distance journeys. Touring bikes are characterized by more relaxed frame angles, heavy chain stays that support the rear panniers, and a long wheelbase (the distance between the wheel axles) for reliable handling. All-round bicycles, known as "hybrids," combine the light weight and speed of sports bikes with the rugged durability of mountain bikes (see pp. 358-359). Bicycles that are not designed for conventional road use include time-trial bikes, which have a short head tube, sloping top tube, "aero" handlebars, and aerodynamic tubing. Most Human Powered Vehicles (HPVs) are recumbents—the rider has a recumbent position—which maximize power output and minimize drag (resistance). Essential to the safety of all riders are helmets, and both front and rear lights; locks protect against theft.



Saddle

EDDY MERCKX RACING BICYCLE





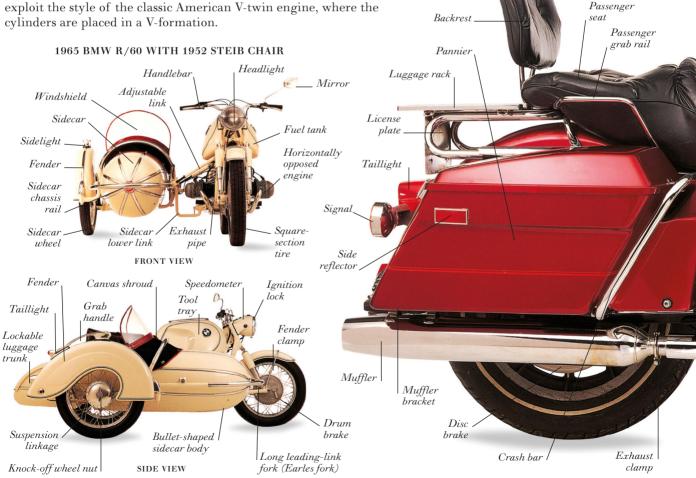
The motorcycle

THE MOTORCYCLE HAS EVOLVED from a motorized cycle—a basic bicycle with an engine—into a sophisticated, high-performance machine. In 1901, the Werner brothers established the most viable location for the engine by positioning it low in the center of the chassis (see pp. 364-365): the new Werner became the basis for the modern motorcycle. Motorcycles are used for many purposes—for commuting, delivering messages, touring, and racing—and different machines have been developed according to the demands of different types of rider. The Vespa scooter, for instance, which is small-wheeled, economical, and easy-to-ride, was designed to meet the needs of the commuter. Sidecars provided transportation for the family until the arrival of cheap cars caused their popularity to decline. Enthusiast riders generally favor larger capacity machines that are capable of greater performance and offer more comfort. Four-cylinder machines have been common since the Honda CB750 appeared in 1969. Despite advances in motorcycle technology, many riders are attracted to the traditional looks of motorcycles like the twin-cylinder Harley-Davidson. The Harley-Davidson Glides exploit the style of the classic American V-twin engine, where the cylinders are placed in a V-formation.

1901 WERNER MOTORCYCLE



1988 HARLEY-DAVIDSON FLHS ELECTRA GLIDE





The motorcycle chassis

THE MOTORCYCLE CHASSIS is the main "body" of the motorcycle, to which the engine is attached. Consisting of the frame, wheels, suspension, and brakes, the chassis performs various functions. The frame, which is built from steel or alloy, keeps the wheels in line to maintain the handling of the motorcycle, and serves as a structure for mounting other components. The engine and gearbox unit is bolted into place, while items such as the seat, the fenders, and the fairing are more easily removable. Suspension cushions the rider from irregularities in the road surface. In most suspension systems, coil springs controlled by an oil damper separate the main mass of the motorcycle from the wheels. At the front, the spring and damper are usually incorporated in a telescopic fork; the rear employs a pivoted swingarm. The suspension also helps to retain maximum contact between the tires and the road, necessary for effective braking and steering. Drum brakes were common until the 1970s, but modern motorcycles use disc brakes, which are more powerful.

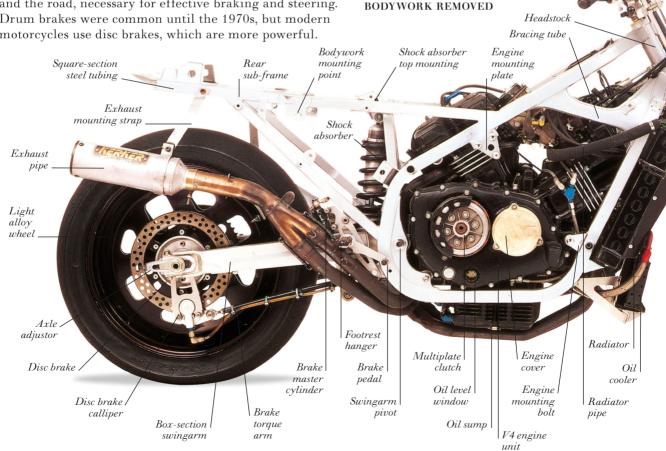
1985 HONDA VF750 WITH BODYWORK

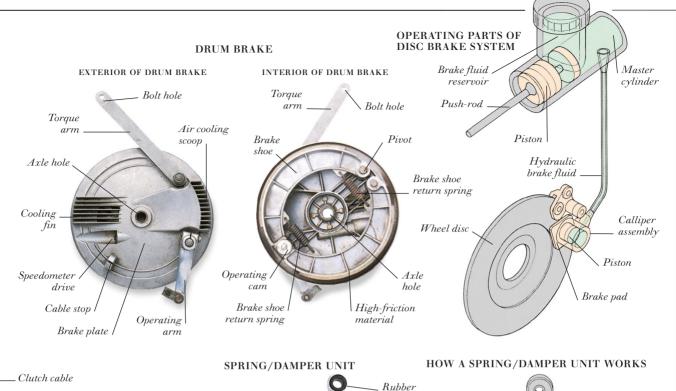


1985 HONDA VF750 WITH

Brake master

cylinder



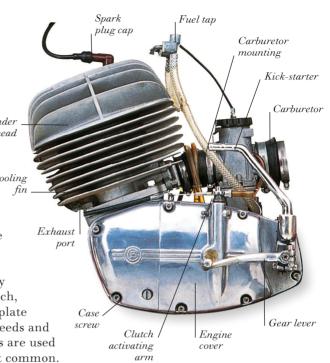


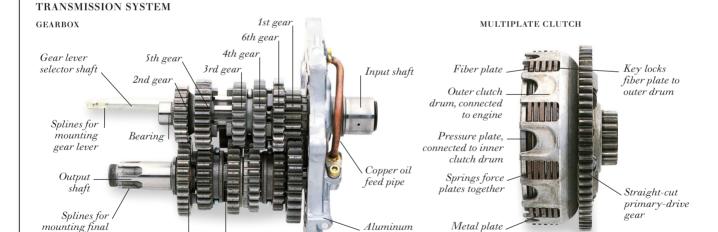


Motorcycle engines

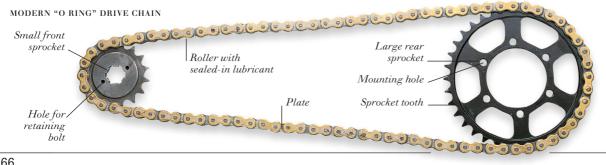
MOTORCYCLE ENGINES must be lightweight and compact and have a good power output. They have between one and six cylinders, can be Cylinder cooled by air or water, and the capacity of the head combustion chamber varies from 49cc (cubic centimeters) to 1500cc. Two types of internal combustion engine are common: the four-stroke, Cooling which is used in cars (see pp. 342-343), and the two-stroke. A basic two-stroke engine has only three moving parts—the crankshaft, the connecting rod, and the piston—but the power output is high. The engine fires every two strokes (rather than every four), giving a "power stroke" every revolution (see p. 343). Power is conveyed from the engine to the rear wheel by the transmission system. This usually consists of a clutch, a gearbox, and a final drive system. Clutches are multiplate devices, which run in oil. Gearboxes have five or six speeds and are operated by foot pedal. Shaft and belt drive systems are used in some cases, but chain drive to the rear wheel is most common.

EXTERIOR OF STANDARD TWO-STROKE ENGINE





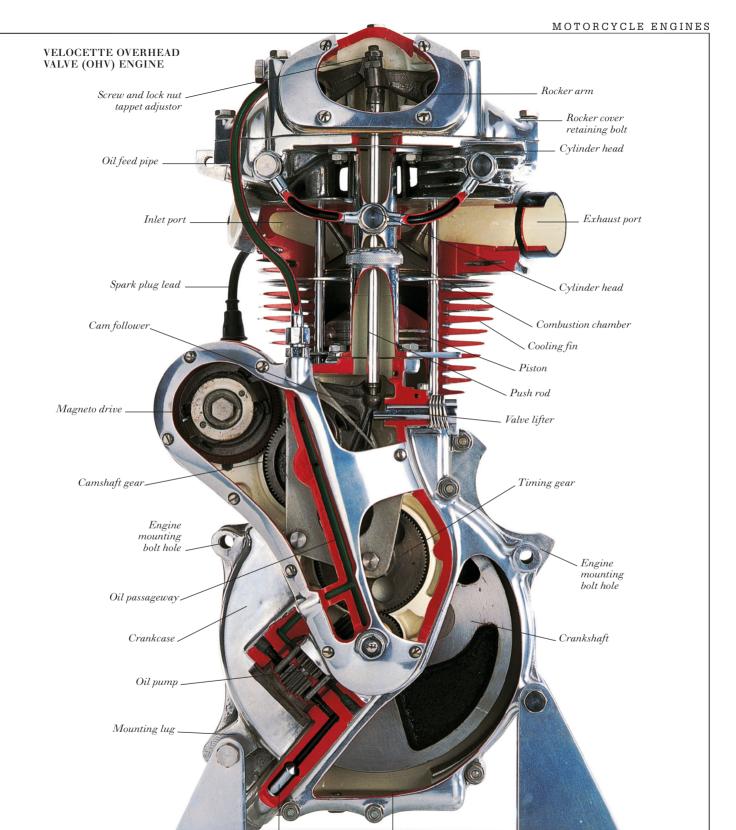
outer casing



Selector fork

drive sprocket

Gear tooth



Nonreturn valve

Oil sump

Competition motorcycles

THERE ARE MANY TYPES of motorcycle sport and in each, a specialized machine has evolved to perform to specific requirements. Races take place on roads or tracks or "off-road," in fields, dirt tracks, and even the desert. "Grand Prix" world championships in road-racing are contested by three classes: 125cc, 250cc twostrokes; the top class of 500cc two-strokes; and 900cc four-stroke machines. The latest racing sidecars have more in common with racing cars than motorcycles. The rider and passenger operate within an all-enclosing, aerodynamic fairing. The Suzuki RGV500 shown here, like other Grand Prix machines. carries advertising, which helps to cover the cost of developing motorcycle technology. In Speedway, which originated in the US in 1902, motorcycles operate without brakes or a gearbox. Off-road competition motorcycles have less emphasis on high power output. In Motocross, for example, which is held on rough terrain, they must have high ground clearance, flexible long-travel suspension, and tires with a chunky tread pattern.

1992 HUSQVARNA MOTOCROSS TC610



Air vent

One-piece seat

and tail unit

Shock

absorber

1992 SUZUKI RGV500 SIDE VIEW

Exhaust pipe

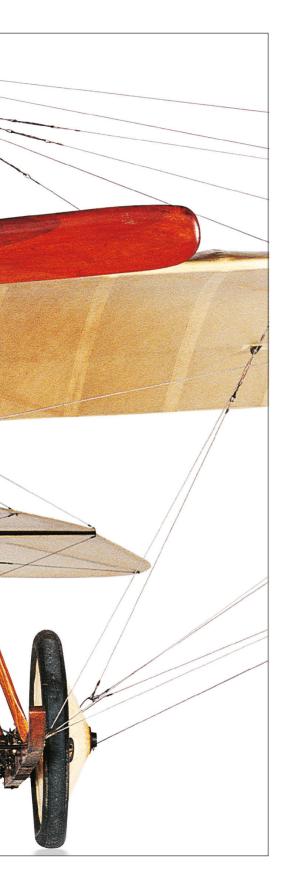
Racing

number









Sea and Air

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A Ship of the Line 380)
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Ancient Greek and Roman ships

ROMAN ANCHOR

Shank Acutely angled Crown

IN THE EXPANSIVE EMPIRES OF GREECE AND ROME, powerful fleets were needed for battle, trade, and communication. Greek galleys were powered by a sail and many oars. A new armament, the embolos (ram), was fitted on to the galley bow. Since ramming duels required fast and maneuverable boats, extra rows of oarsmen were added, culminating in the trireme. During the fifth and fourth centuries BC, the trireme

Double halyard

Bullseve

dominated the Mediterranean. It was powered by 170 oarsmen, rowing with one oar each. The oarsmen were ranged on three levels, as the model opposite shows. The trireme also carried archers and soldiers for boarding. Galleys were pulled out of the water when not in use, and were Roband kept in dockyard ship-sheds. The merchant ships of the Greeks

and Romans were mighty vessels, too. The full-bodied Roman

corbita, for example, could hold up to 400 tons (440 metric tons) and

Antenna

(vard)

Oculus

Tabling

Bolt rope

Prow

(eve)

(rope band)

ROMAN CORBITA

Fore stay

Fore mast

Buntline

Brace

Ceruchi

Ring

(lift)

Anchor

Heraldic device

Ruden

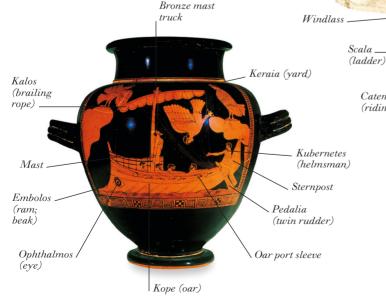
(brail line)

Sheet

carried a cargo of spices, gems, silk, and animals. The construction of these boats was based on a stout hull with planking secured by mortice and tenon. Some of these ships embarked on long voyages, sailing even as far as India. To make them easier to steer, corbitas set a fore sail called an "artemon." It flew from a forwardleaning mast that was a forerunner of the long bowsprits carried by the great clipper ships of the 19th century.

Artemon (fore sail)

ATTIC VASE SHOWING A GALLEY



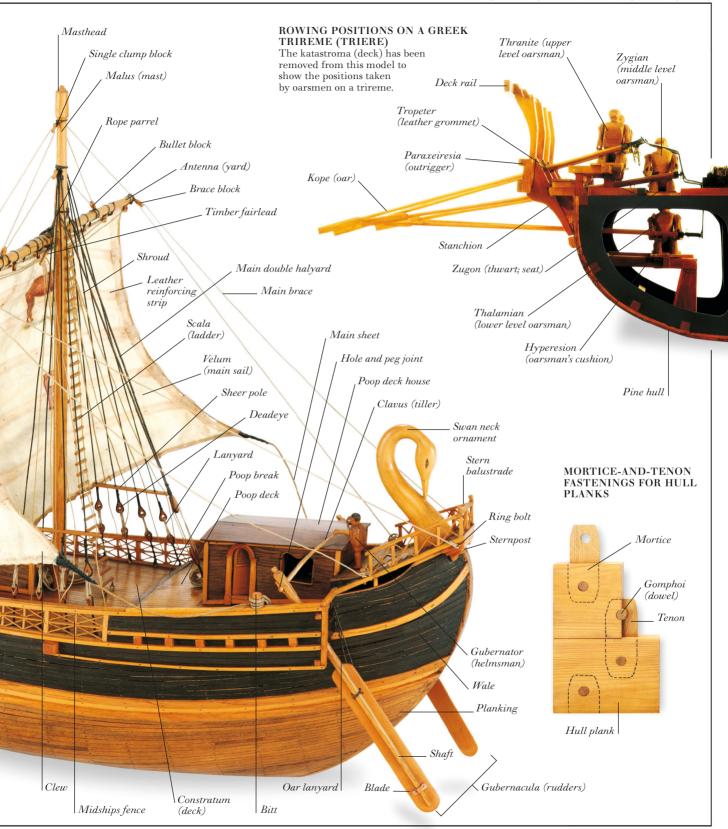
Catena (riding bitt) Ancorale.

(anchor rope; anchor rode)

> Hatch board Deck beam

> > Zosteres (rubbing strake)

Cargo hold



Zoomorphic head

Braiding

Serpentine neck

Lozenge-shaped

Sternpost

Boss (rudder pivot)

> Steering oar (side rudder)

Rectangular cross-band

Viking ships

IN THE DARK AGES and early medieval times, the longships of Scandinavia were one of the most feared sights for people of northern Europe. The Vikings launched raids from Scandinavia every summer in longships equipped with a single steering oar on the right, or "steerboard," side (hence "starboard"). A longship had one row of oars on each side and a single sail. The hull had clinker (overlapping) planks. Prowheads adorned fighting ships during campaigns of war. The sailing longship was also used

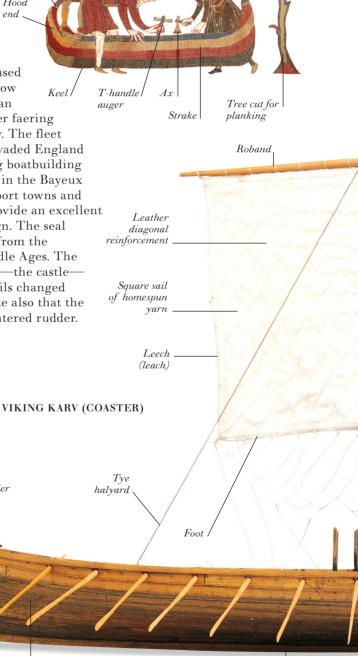
> for local coastal travel. The kary below was probably built as transport for an important family, while the smaller faering (top right) was a rowing boat only. The fleet of William of Normandy that invaded England in 1066 owed much to the Viking boatbuilding tradition, and has been depicted in the Bayeux Tapestry (above). Seals used by port towns and royal courts through the ages provide an excellent record of contemporary ship design. The seal opposite shows how ships changed from the Viking period to the end of the Middle Ages. The introduction of the fighting platform—the castle and the addition of extra masts and sails changed the character of the medieval ship. Note also that the steering oar has been replaced by a centered rudder.

> > Tiller

Oar

Starboard (steerboard) side

Snake-tail ornament



BOATBUILDERS'

Breast auger

Shave

Sheer

Master

shipwright

Stempost

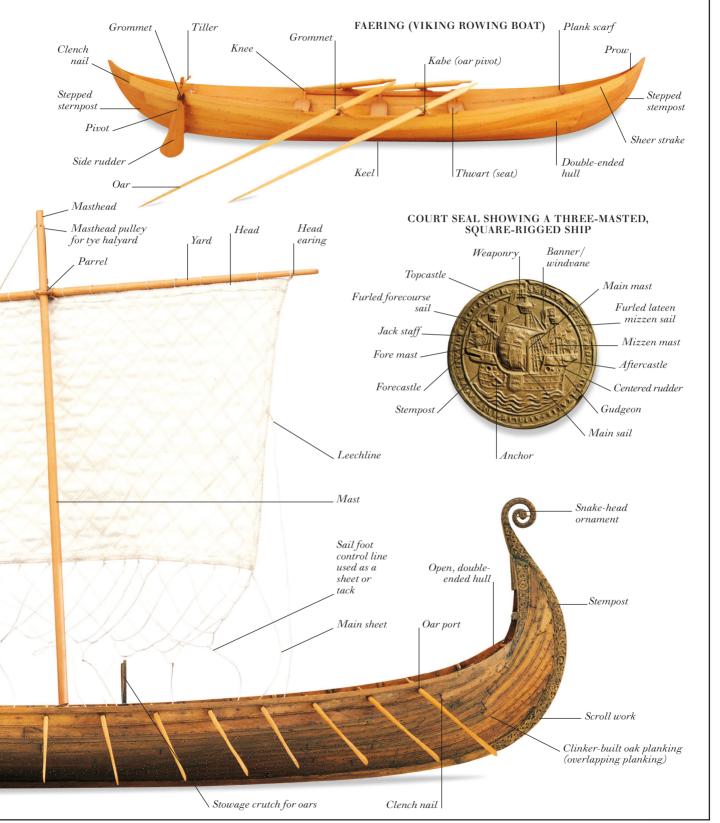
Hood

end

Broad ax

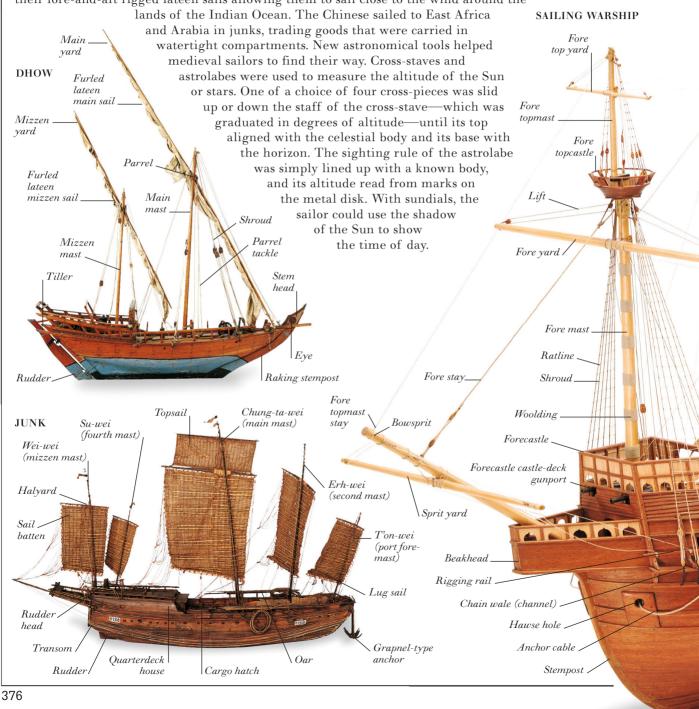
TOOLS

DRAGON PROWHEAD



Medieval warships and traders

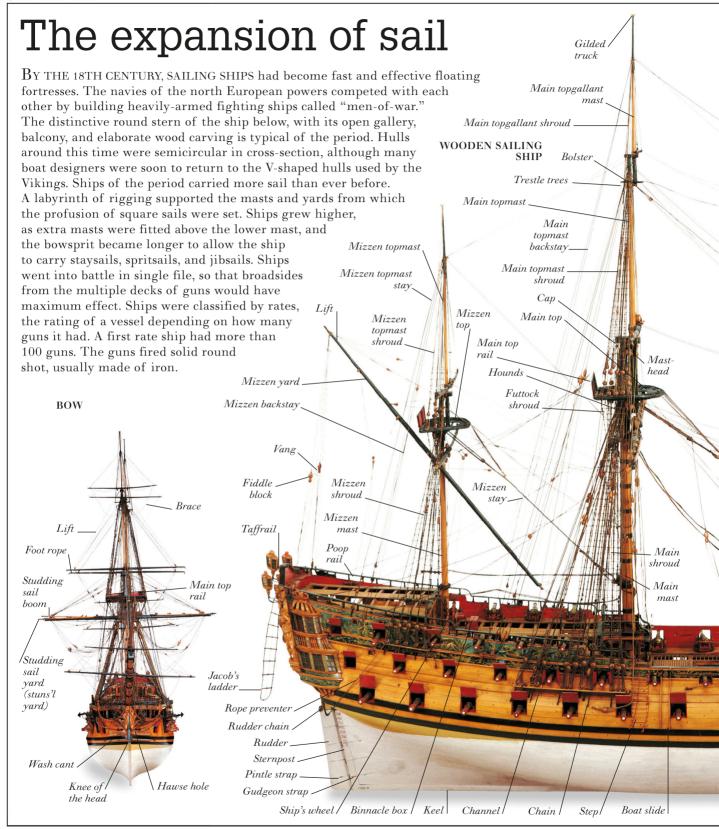
FROM THE 16TH CENTURY, SHIPS WERE BUILT WITH A NEW FORM OF HULL, constructed from carvel (edge-to-edge) planking. Warships of the time, like King Henry VIII of England's Mary Rose, boasted awesome fire power. This ship carried both long-range cannon in bronze, and short-range, anti personnel guns in iron. Elsewhere, ships took on a multiformity of shapes. Dhows transported slaves from East Africa to Arabia, their fore-and-aft rigged lateen sails allowing them to sail close to the wind around the

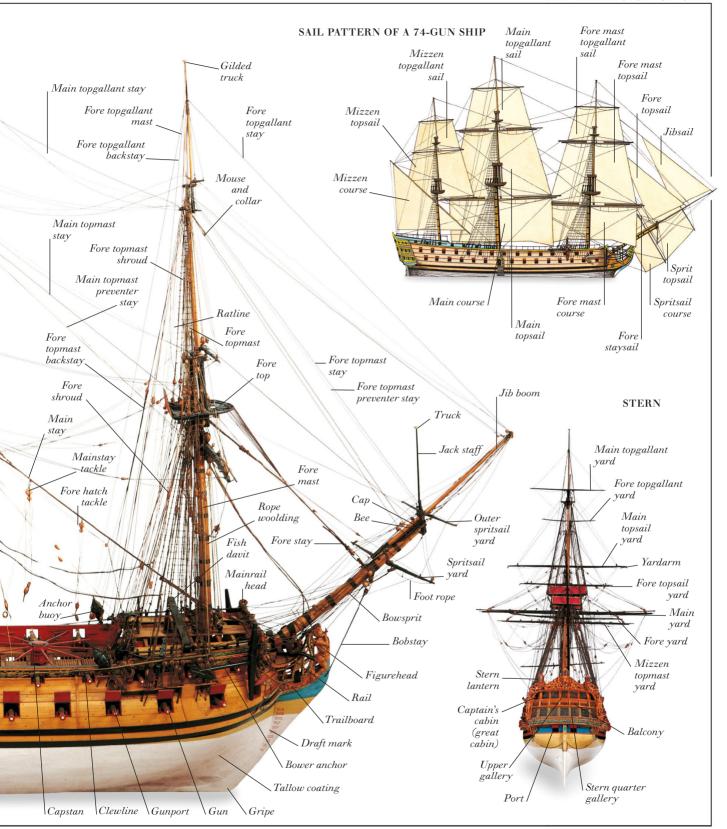


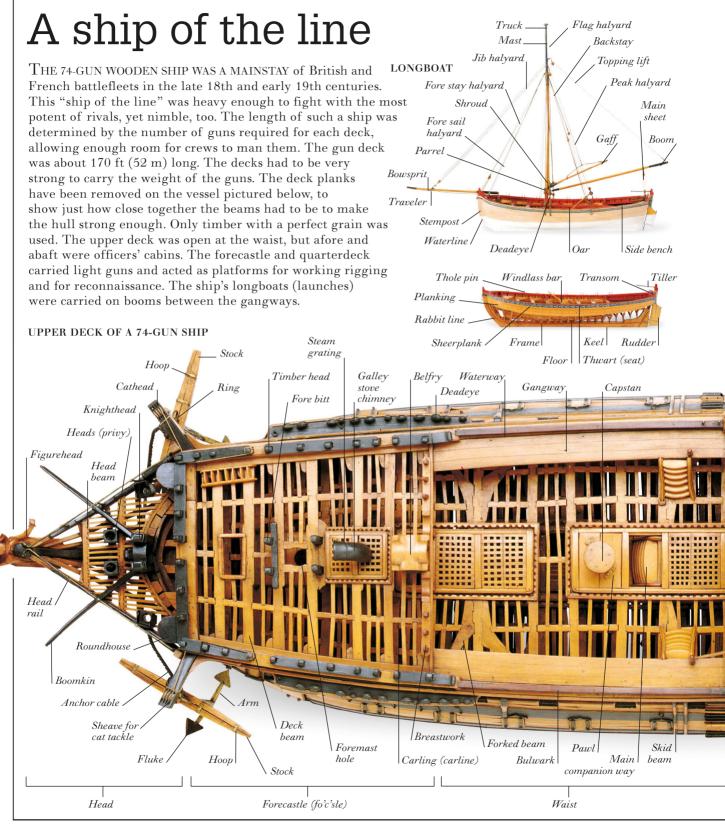
Port bower anchor

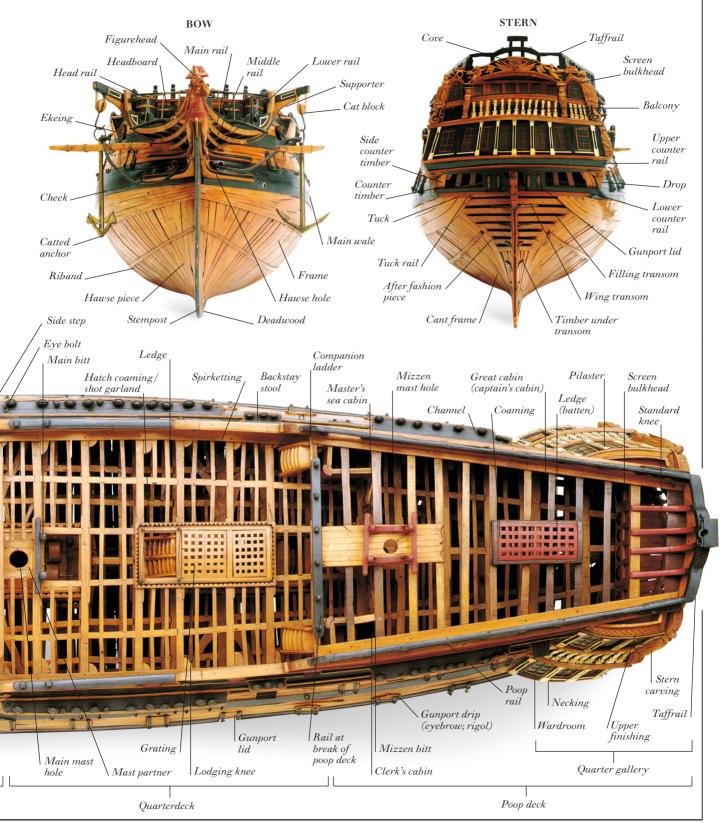
(sighting rule)

Bottom ballast

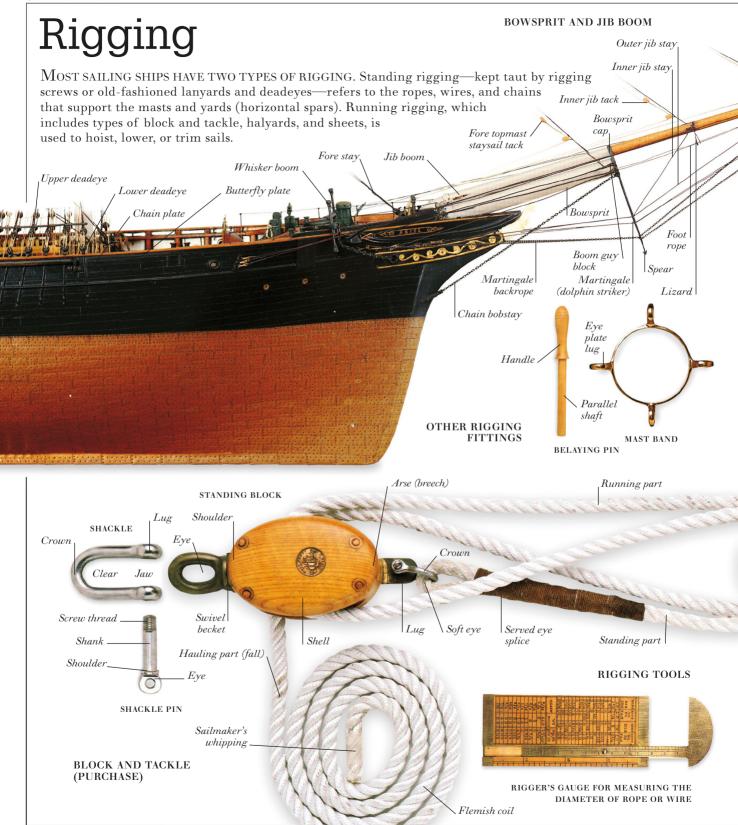








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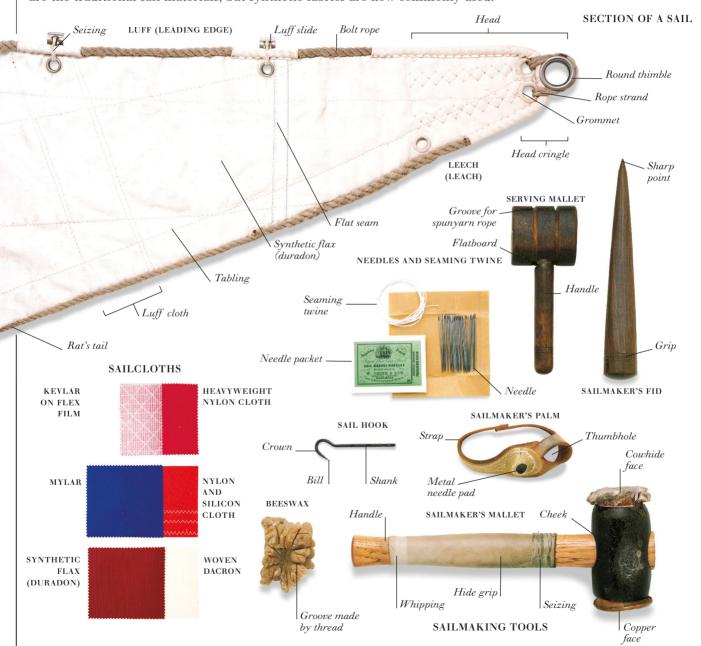


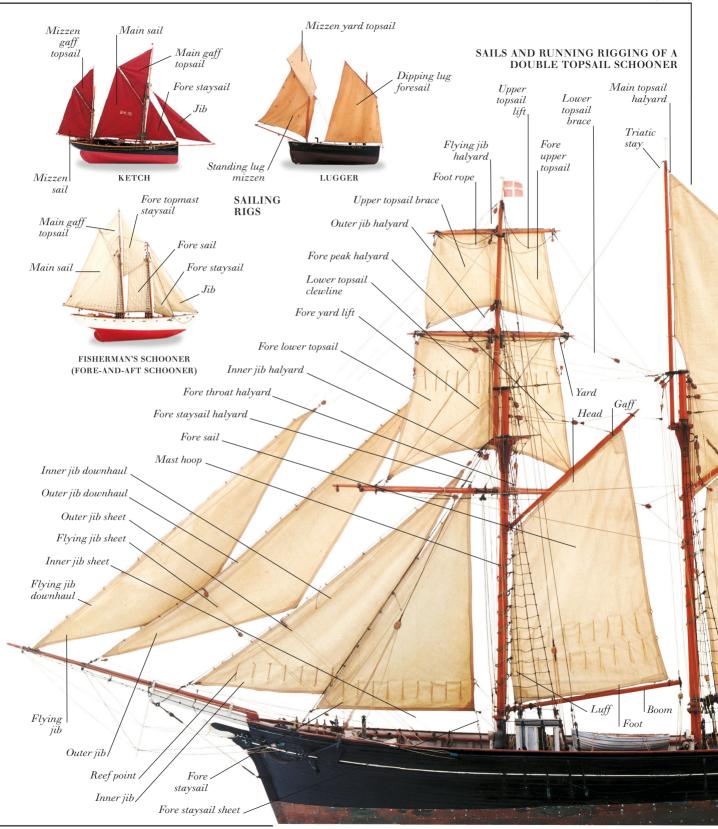


Sails

PARREL BEADS

THERE ARE TWO MAIN TYPES OF SAIL, often used in combination. Square sails are driving sails. They are usually attached by parrels to yards, square to the mast to catch the following wind. On fore-and-aft sails, such as lateen and lug sails, the luff (leading edge) usually abuts a mast or a stay. The head of the sail may abut a gaff, and the foot a boom. Around the world, a great range of rigs (sail patterns), such as the ketch, lugger, and schooner, have evolved to suit local needs. Sails are made from strips of cloth, cut to give the sail a belly and strong enough to resist the most violent of winds. Cotton and flax are the traditional sail materials, but synthetic fabrics are now commonly used.





TYPES

CLOSE-STOWING

Mooring and anchoring

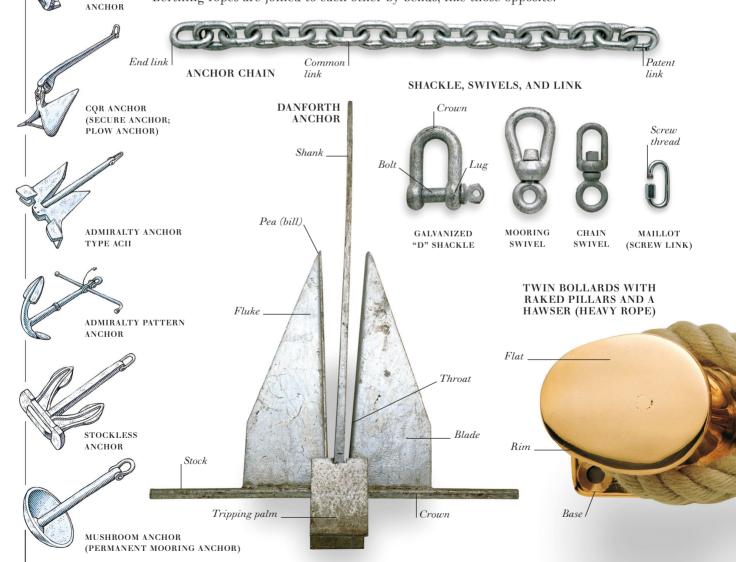
FOR LARGE VESSELS IN OPEN WATER, ANCHORAGE IS ESSENTIAL. By holding a ship securely STONE ANCHOR to the seabed, an anchor prevents the vessel from being at the mercy of wave, tide, (KILLICK) and current. The earliest anchors were nothing more than stones. In later years,

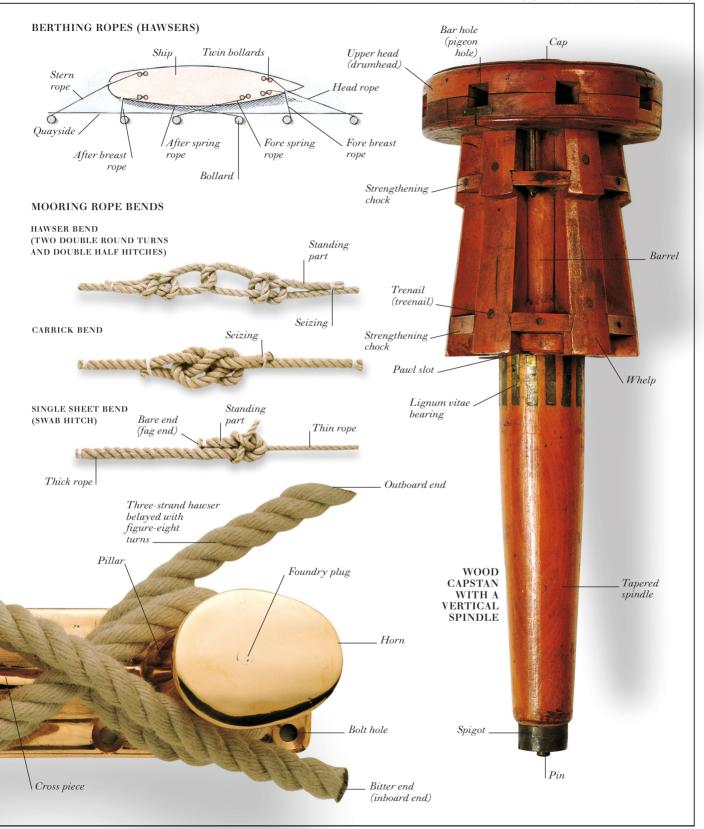
> Rope hole

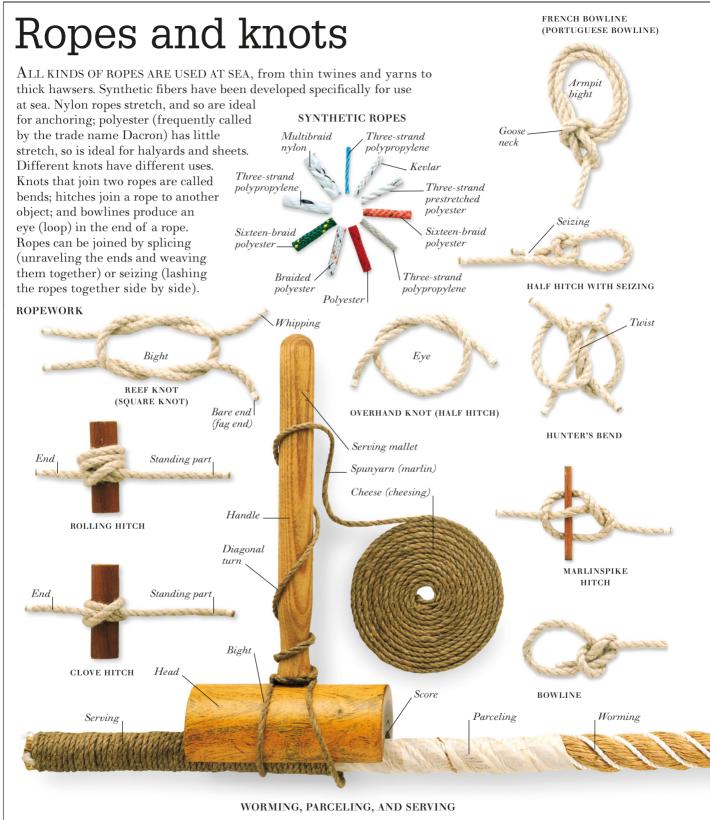
many anchors had a standard design, much like the Admiralty pattern anchor shown on this page. The Danforth anchor is somewhat different. It has particularly deep flukes to give it great holding power. On OF ANCHOR

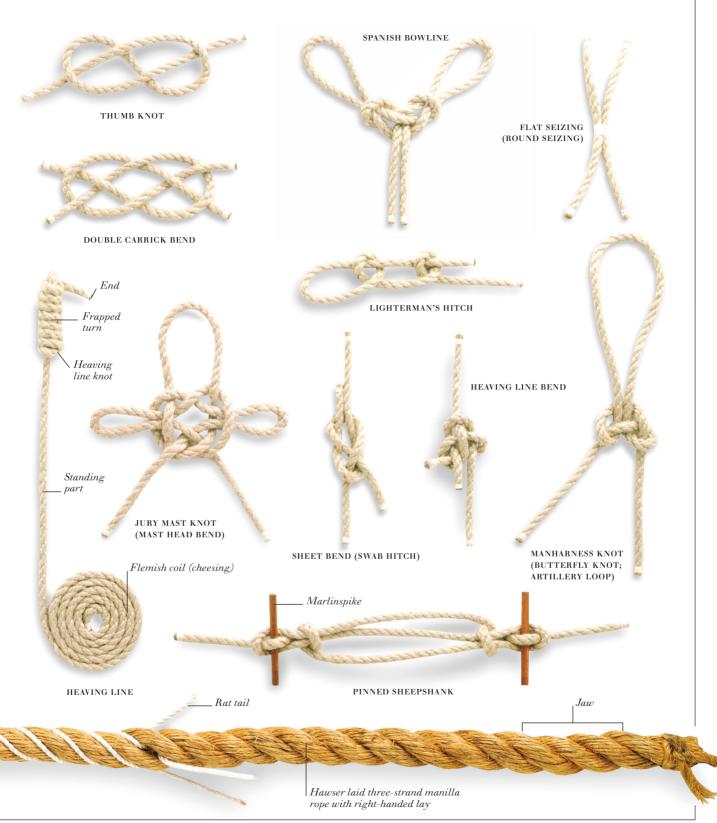
large sailing ships, anchors were worked by teams of sailors. They turned the drum of a capstan by pushing on bars slotted into the revolving cylinder. This, in turn, lifted or

lowered the anchor chain. In calm harbors and estuaries, ships can moor (make fast) without using anchors. Berthing ropes can be attached to bollards both inboard and on the quayside. Berthing ropes are joined to each other by bends, like those opposite.









Paddle wheels and propellers

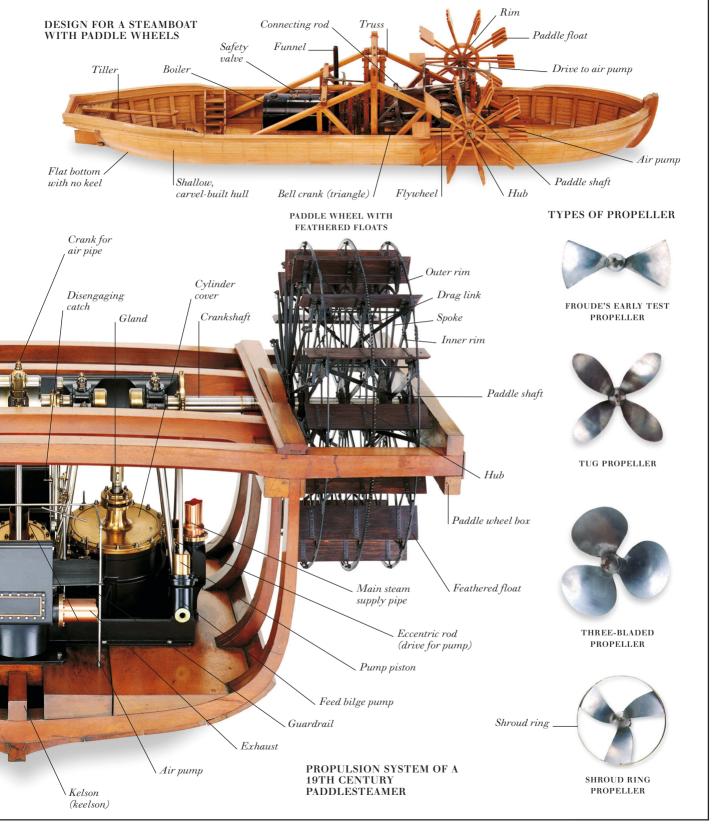
THE INVENTION OF THE STEAM ENGINE IN THE 18TH CENTURY made mechanically driven ships fitted with paddle wheels or propellers a viable alternative to sails. Paddle wheels have fixed or feathered floats, and the model shown below features both types. Feathered floats give more propulsive power than fixed floats because they are almost upright at all times in the water. Paddle wheels were superseded by the propeller on oceangoing

vessels in the mid-19th century. Propellers are more efficient, work better in rough water, and are less vulnerable in collisions. The first propellers were two-bladed but later three-SHIP'S WHEEL and four-bladed versions are more powerful; the shape and pitch of blades have also been King spoke refined over the years. At the beginning of the 18th century, tillers were superseded on handle many larger ships by the ship's wheel as a means of steering. Handle PADDLE WHEEL WITH FIXED FLOATS Slip eccentric Spoke for slide valve Rim plate OSCILLATING Wrist pin STEAM ENGINE Ahead/astern controls Felloe Slide valve (rim section) LimbMain crank Maker's name Fixed float Nave plate HubNave Deck beam THREE-BLADED PROPELLER Blade Tapered shaft holeHubStrutFrame Piston rod (tail rod) Stuffing box Keyway Oscillating cylinder Pitch Propeller blade Bottom plate (bedplate) tip trace Propellerdiameter Blade Slide valve rod **PROPELLER** ACTION Control

platform

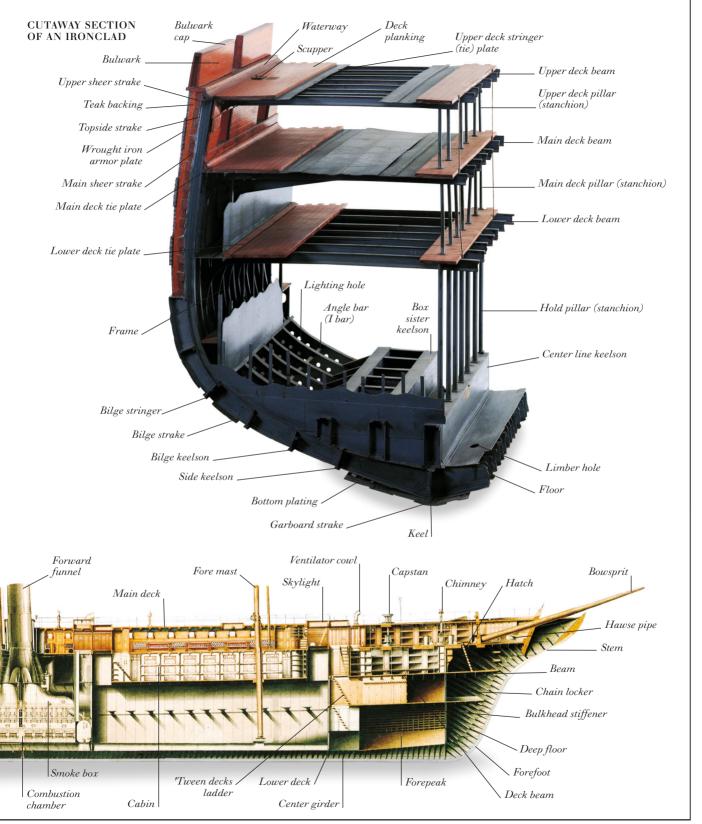
Hub

Propeller hub trace



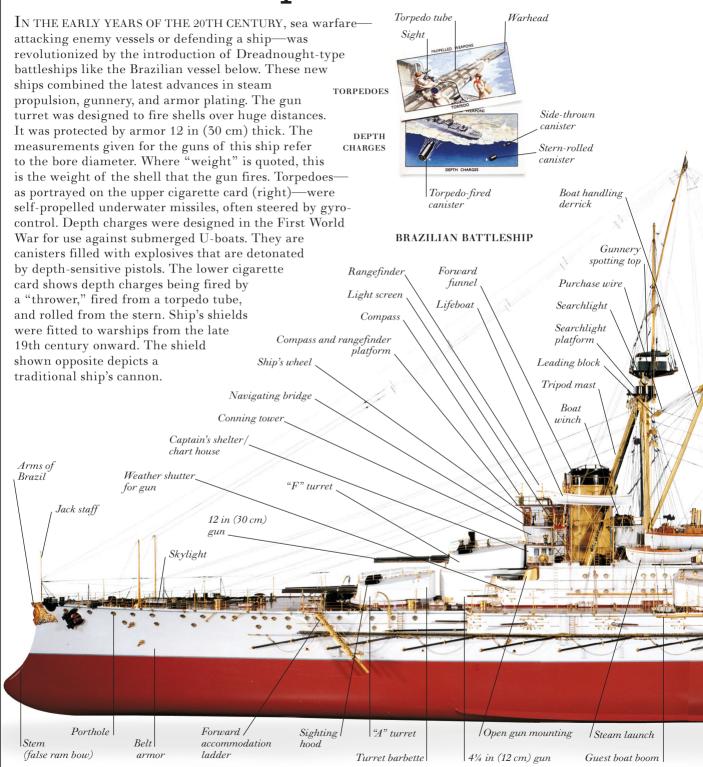
Anatomy of an iron ship

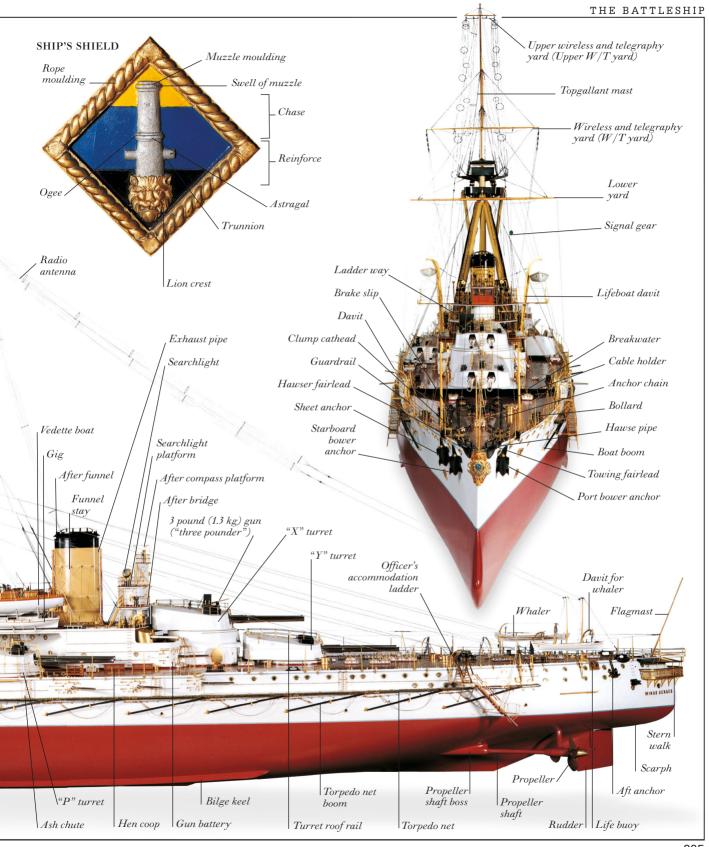
 $\overline{ ext{I}}$ RON PARTS WERE USED IN THE HULLS OF WOODEN SHIPS AS EARLY AS 1675, often in the same form as the wooden parts that they replaced. Eventually, as on the tea clipper Cutty Sark (below), iron rigging was found to be stronger than the traditional rope. The first "ironclads" were warships whose wooden hulls were protected by iron armor plates. Later ironclads actually had iron hulls. Steel yard Iron wire stay The model opposite is based on the British warship HMS Warrior, launched in 1860, the first battleship built entirely of iron. The plan of the Steel lower mast iron paddlesteamer (bottom), built somewhat later, shows that this vessel was a sailing ship; but it also boasted a steam propulsion Steel bowsprit plant amidships that turned two side paddlewheels. Early iron hulls were made from plates that were painstakingly riveted together (as below), but by the 20th century vessels began to be welded together. whole sections at a time. The Second World War "liberty ship" was one of the first of these Wooden "production-line vessels." Forged planking with iron copper sheathing anchor RIVETTED PLATES Pan head rivet Accommodation section Cargo derrick LIBERTY Plate Weld line SHIP Gunsection Button head Seam rivet (snap head) PLAN OF AN IRON Cargo hold Stern section Midships section Bow section **PADDLESTEAMER** Paddle Crankshaft wheel Steam whistle Guardrail Main mast Mizzen Poop Deck lantern Connecting Lounge After funnel *Eccentric* Steering State room deck position Guardrail Binnacle Skylight Steering gear Stern Vertical frame ladder Mast step Rudder Rudder post Reversing Side Tank wheel lever Heel of. Bar keel Afterpeak Main mast step Box boiler rudder post Cabin Donkey boiler Bottom plate Cylinder Foundation Stern framing



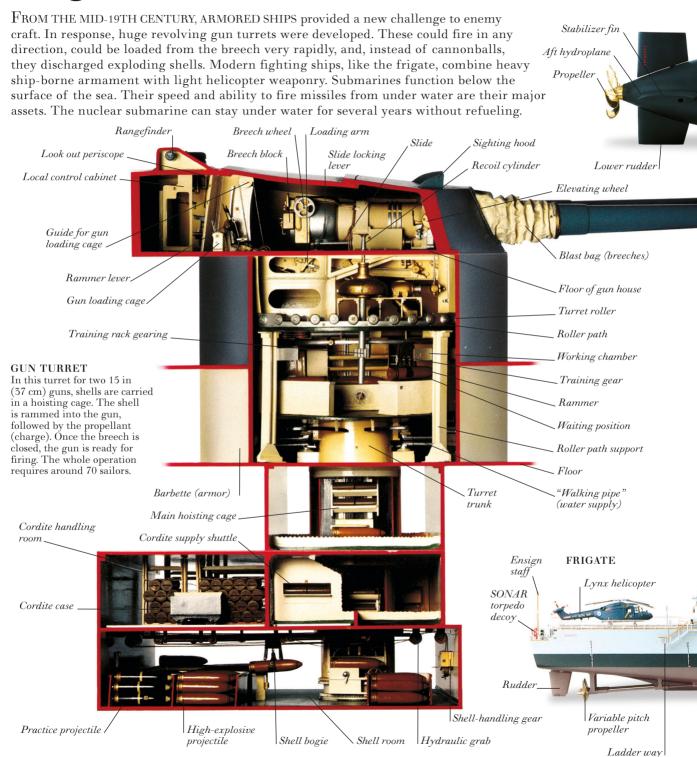
The battleship

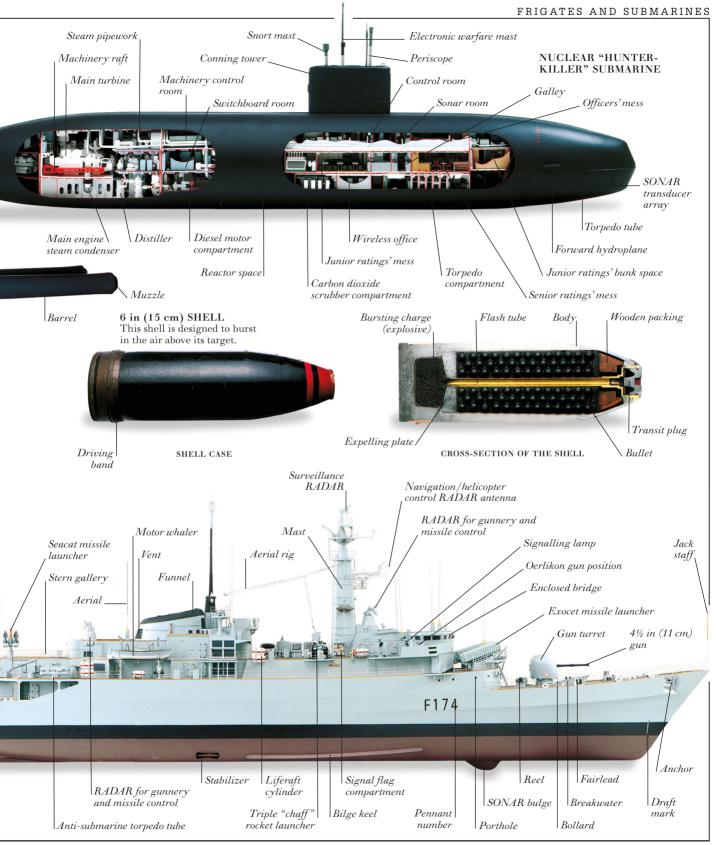
20TH CENTURY WEAPONRY

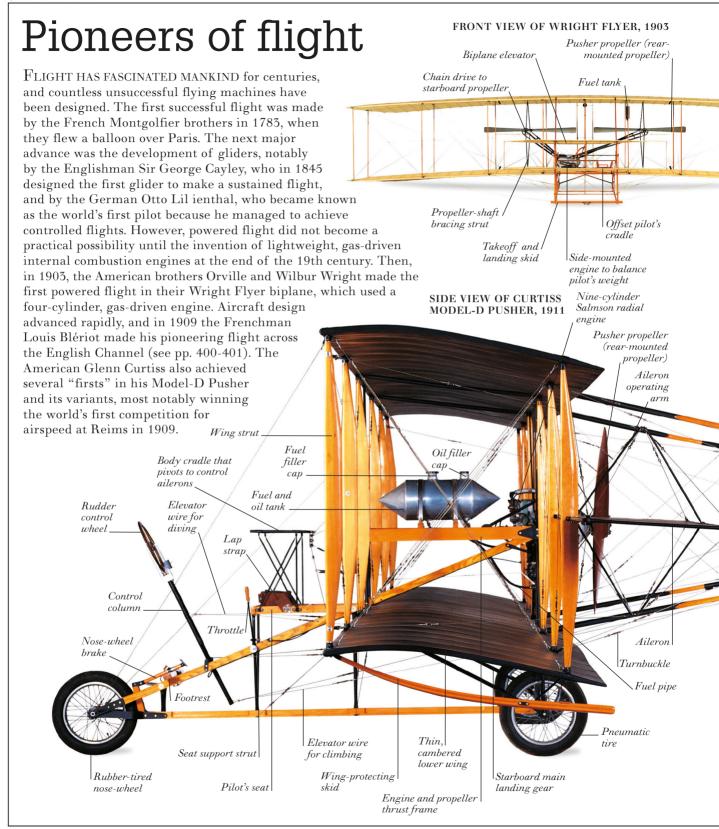


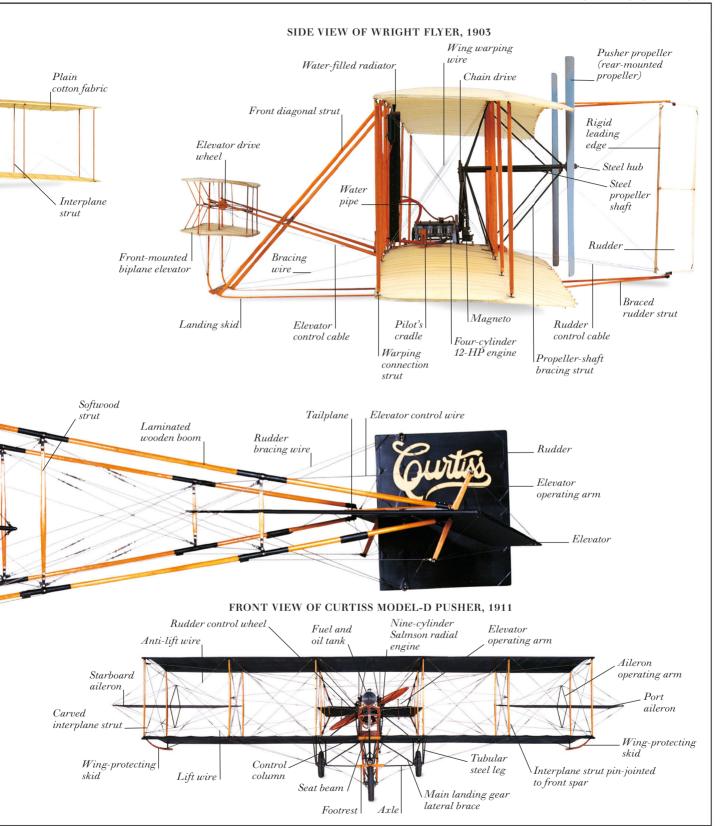


Frigates and submarines









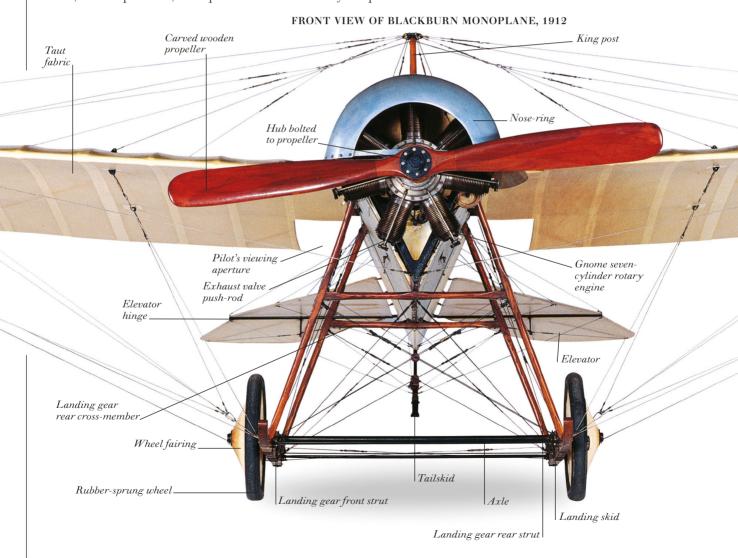
Early monoplanes

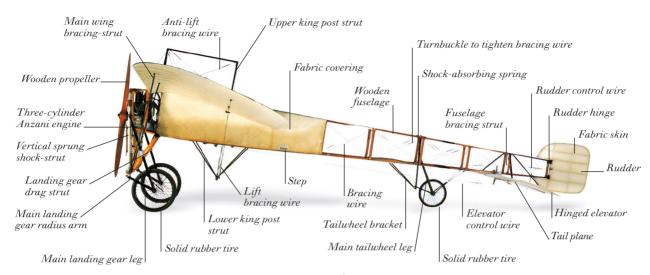


RUMPLER MONOPLANE, 1908

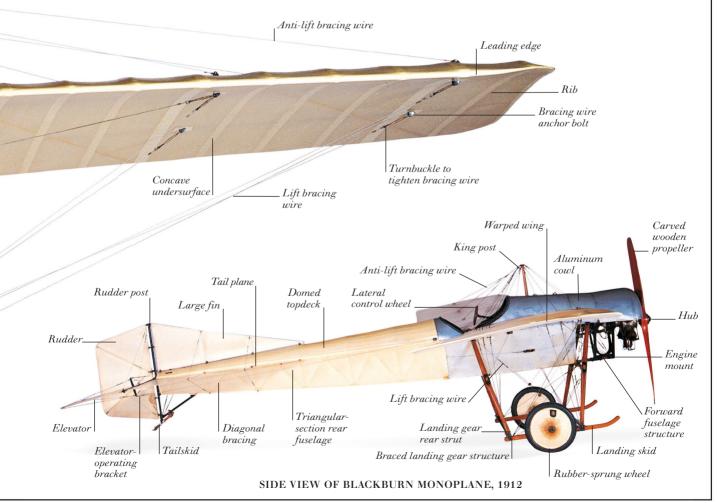
MONOPLANES HAVE ONE WING on each side of the fuselage. The principal disadvantage of this arrangement in early, wooden-framed aircraft was that single wings were weak and required strong wires to brace them to king posts above and below the fuselage. However, single wings also had advantages: they experienced less drag than multiple wings, allowing greater speed; they also made aircraft more manoeuvrable because single wings were easier to warp (twist) than double wings, and warping the wings was how pilots controlled the roll of early aircraft. By 1912, the French pilot Louis Blériot had

used a monoplane to make the first flight across the English Channel, and the Briton Robert Blackburn and the Frenchman Armand Deperdussin had proved the greater speed of monoplanes. However, a spate of crashes caused by broken wings discouraged monoplane production, except in Germany, where all-metal monoplanes were developed in 1917. The wings of all-metal monoplanes did not need strengthening by struts or bracing wires, but despite this, such planes were not widely adopted until the 1930s.

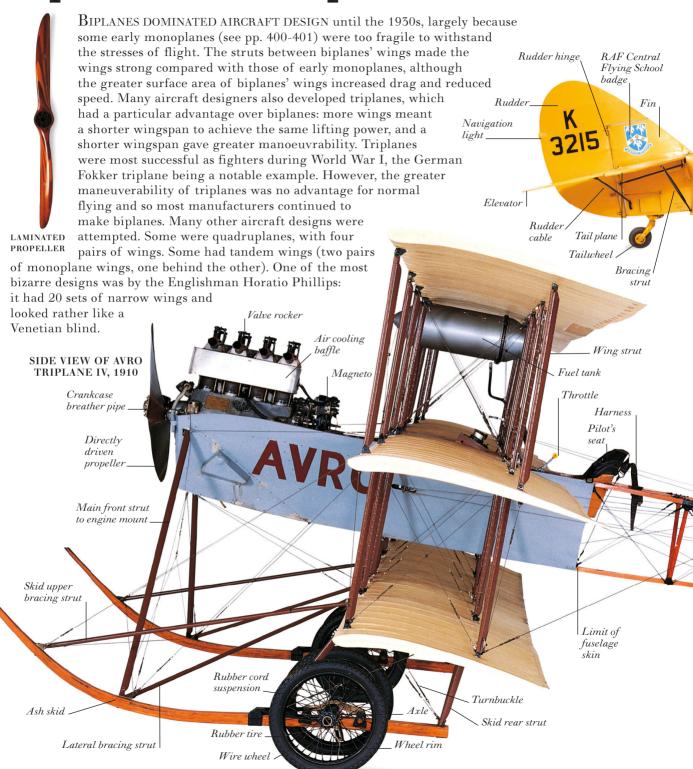


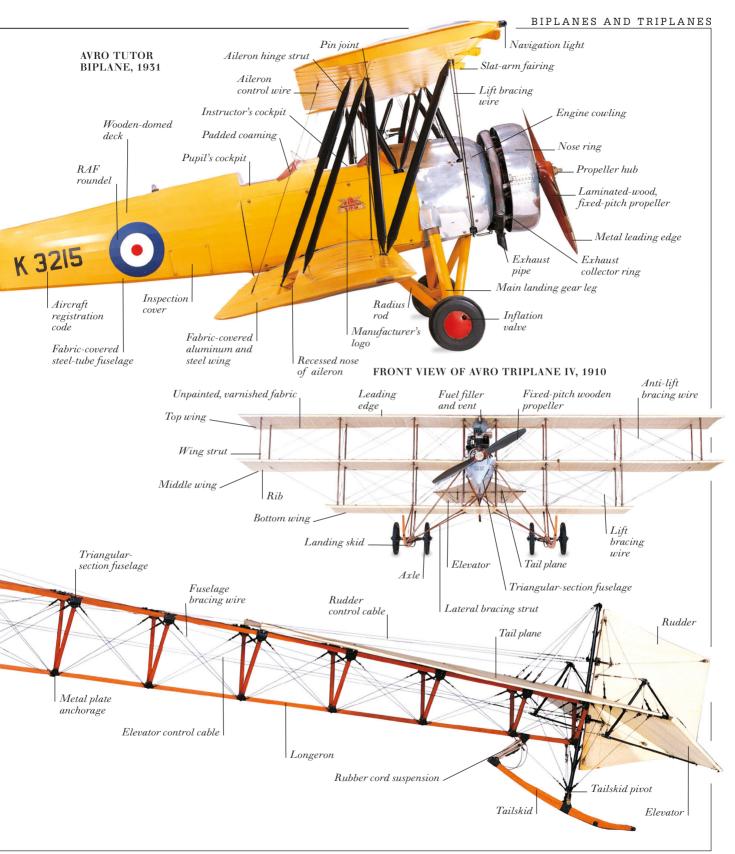


SIDE VIEW OF BLÉRIOT XI, 1909



Biplanes and triplanes





FLYING

HELMET

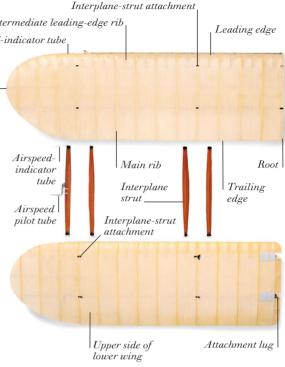
World War I aircraft

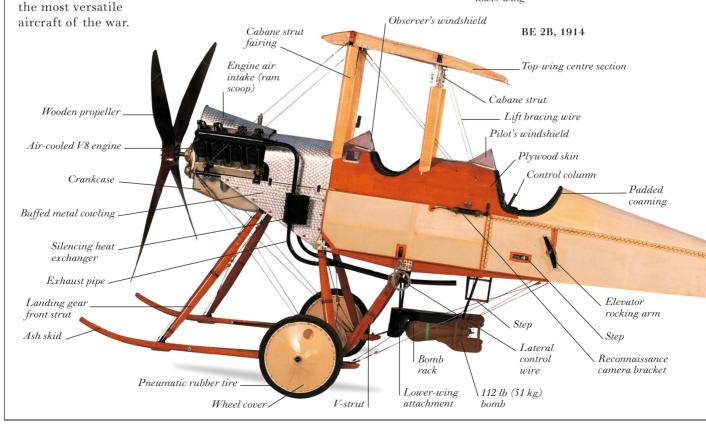
PORT WINGS FROM A BE 2B

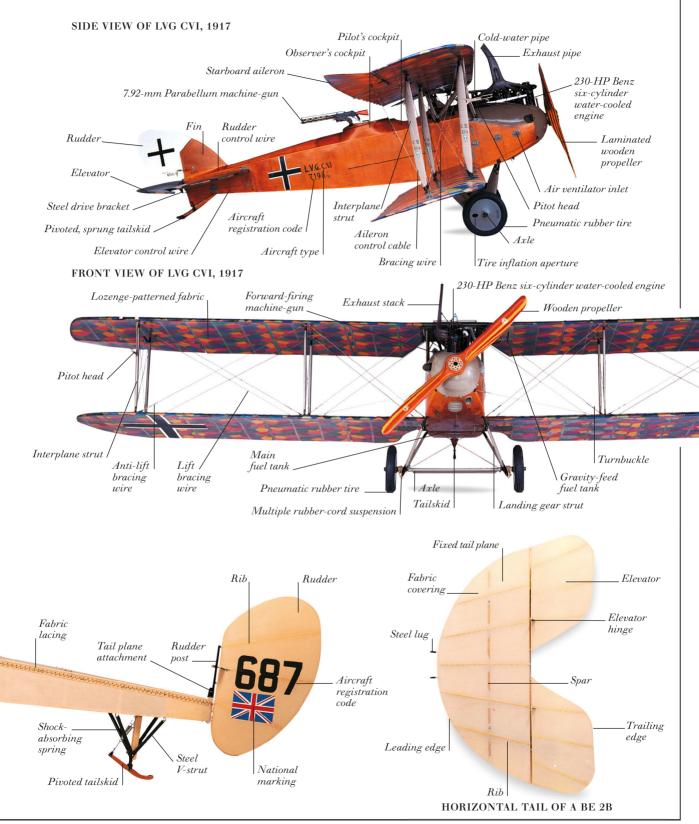


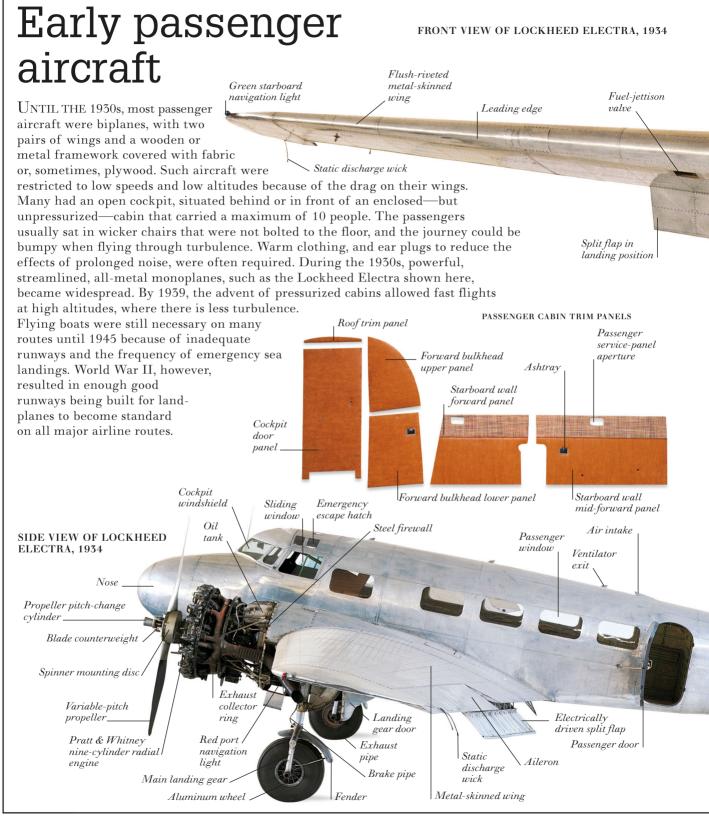
WHEN WORLD WAR I STARTED in 1914, the main purpose of military aircraft was reconnaissance. The British-built BE 2, of which the BE 2B was a variant, was wellsuited to this duty; it was very stable in flight, allowing the occupants to study the terrain, take photographs, and make notes. The BE 2 was also one of the first aircraft to drop bombs. One of the biggest problems for aircraft

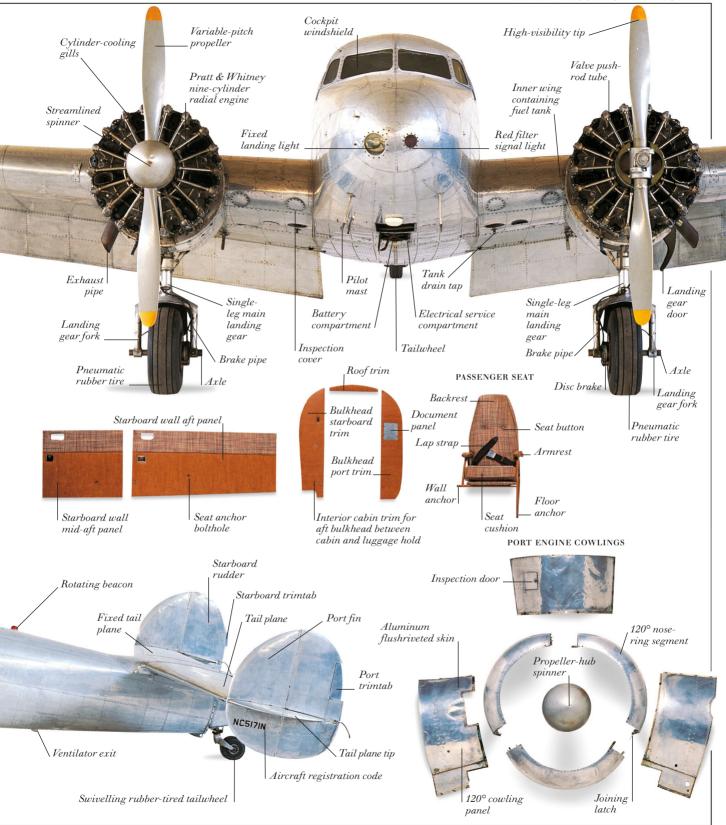
designers during the war was mounting machine-guns. On aircraft that had front-mounted propellers, the field of fire was restricted by the propeller and other parts of the aircraft. The problem was solved in 1915 by the Dutchman Anthony Fokker, who designed an interrupter gear that prevented a machine-gun from firing when a propeller blade passed in front of the barrel. The German LVG CVI had a forward-firing gun to the right of the engine, as well as a rear-cockpit gun, and a bombing capability. It was one of









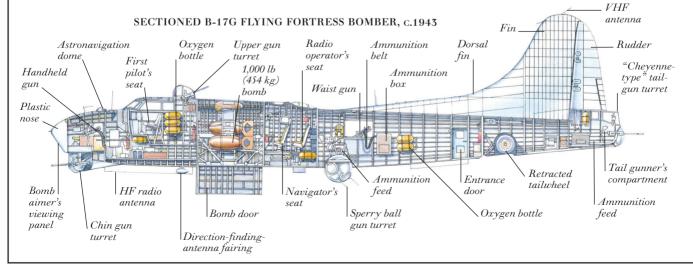


World War II aircraft

WHEN WORLD WAR II began in 1939, air forces had already replaced most of their fabric-skinned biplanes High-visibility yellow tip with all-metal, stressed-skin monoplanes. Aircraft played a far greater role in military operations during World War II than ever before. The wide range of aircraft duties, and the introduction of radar tracking and guidance systems, put pressure on designers to improve aircraft performance. The main areas of improvement were speed, range, and engine power. Bombers became larger and more powerful—converting from Variable-pitch aluminum-alloy two to four engines-in order to hlade carry a heavier bomb load; the US B-17 Flying Fortress could carry up to 6.8 tons (6.2 metric tons) of

bombs over a distance of about 2,000 miles (3,200 km). Some aircraft increased their range by using drop tanks (fuel tanks that were jettisoned when empty to reduce drag). Fighters needed speed and manoeuvrability: the Hawker Tempest shown here had a maximum speed of 435 mph (700 km/h), and was one of the few Allied aircraft capable of catching the German jet-powered V1 "flying bomb." By 1944, Britain had introduced its first turbojetpowered aircraft, the Gloster Meteor fighter, and Germany had introduced the fastest fighter in the world, the turbojet-powered Me 262, which had a maximum speed of 540 mph (868 km/h).

STARBOARD ENGINE Radiator COWLINGS access cowling Lower sidecowling Cowling fastener Upper sidecowling Cartridge 2,400-HP Napier Sabre starter 24-cylinder engine Propeller governor Radiator header tank Propeller drive shaft Magneto Ejector exhaust Starter motor COMPONENTS OF A HAWKER TEMPEST Engine top MARK V, c.1943 cowling Cowling fastener Upper sidecowling. Lower side cowling PORT Radiator-access ENGINE cowling COWLINGS

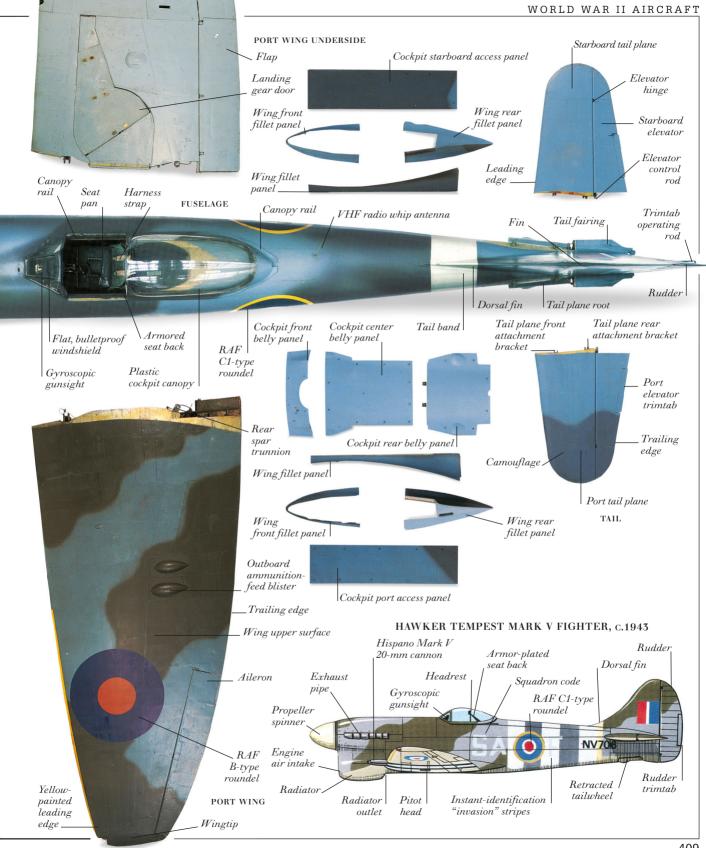


PROPELLER

Light-alloy

propeller

spinner



Modern piston aero-engines



MID WEST TWO-STROKE, THREE-CYLNDER ENGINE

PISTON ENGINES today are used mainly to power the vast numbers of light aircraft and microlights, as well as crop-sprayers and crop-dusters, small helicopters, and firebombers (which dump water on large fires). Virtually all

Reduction

Sprag

clutch

gearbox

Torsional

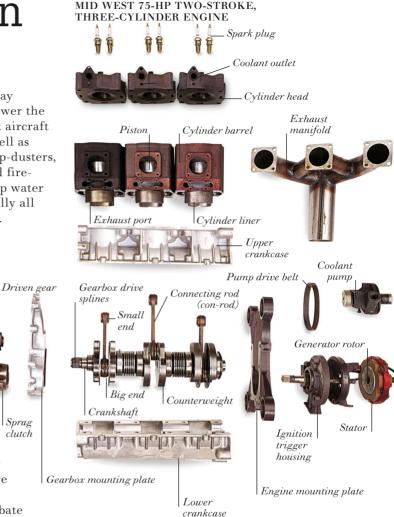
vibration

damper

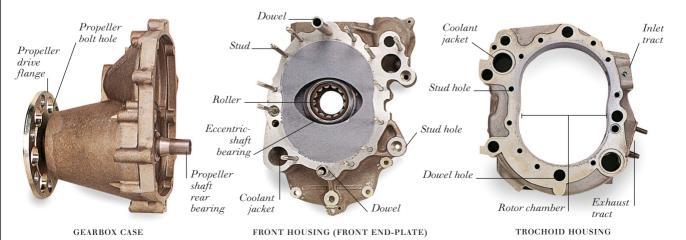
heavier aircraft are now powered by jet engines. Modern piston aero-engines work on the same basic principles as the engine

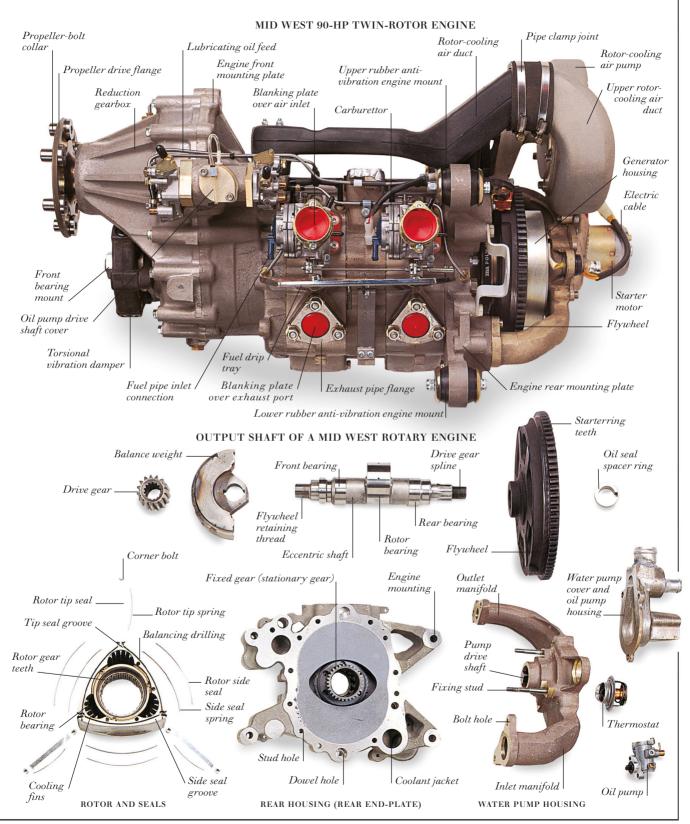
used by the Wright brothers in the first powered flight in 1903. However, today's engines are more sophisticated than earlier engines. Propeller For example, modern drive flange aero-engines may use a two-stroke or a four-stroke combustion cycle; they may have from one to nine air- or water-cooled cylinders, which may be arranged horizontally,

in-line, in V formation, or radially; and they may drive the aircraft's propeller either directly or through a reduction gearbox. One of the more unconventional types of modern aero-engine is the rotary engine shown here, which has a trilobate (three-sided) rotor spinning in a chamber shaped like a fat figure-eight.



ROTOR AND HOUSINGS OF A MID WEST SINGLE-ROTOR ENGINE





Modern jetliners 1



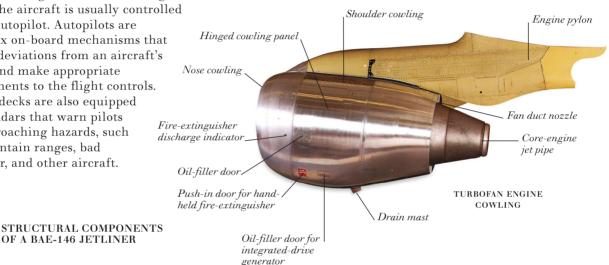
BAE-146 JETLINER

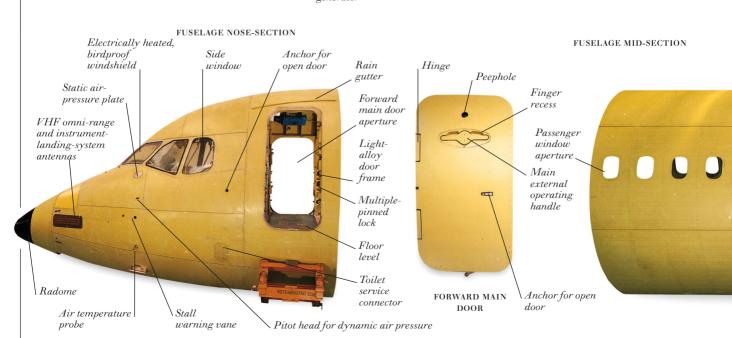
MODERN JETLINERS HAVE ENABLED ordinary people to travel to places where once only the wealthy could afford to go. Compared with the first jetliners (which were introduced in the 1940s), modern ones are much quieter, burn fuel more efficiently, and produce less air pollution. These advances are largely due

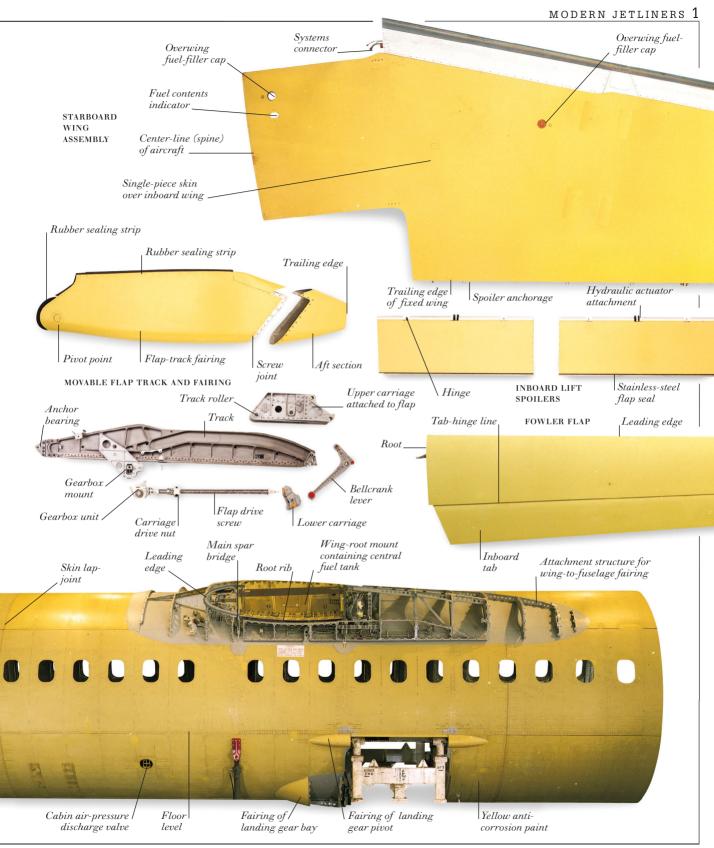
to the replacement of turbojet engines with turbofan engines (see pp. 418-419). The greater power of turbofan engines at low speeds enables modern jetliners to carry more fuel and passengers than turbojet aircraft; a modern Boeing 747-400 (popularly known as a "jumbo jet") can fly 400 people for 8,500 miles (13,700 km) without needing to refuel. Jetliners fly at high altitudes, typically cruising at 26,000-36,000 ft (8000-11,000 m), where they can use fuel efficiently and usually avoid bad weather. The pilot always controls the aircraft during takeoff and landing, but at other

times the aircraft is usually controlled by an autopilot. Autopilots are complex on-board mechanisms that detect deviations from an aircraft's route and make appropriate adjustments to the flight controls. Flight decks are also equipped with radars that warn pilots of approaching hazards, such as mountain ranges, bad weather, and other aircraft.

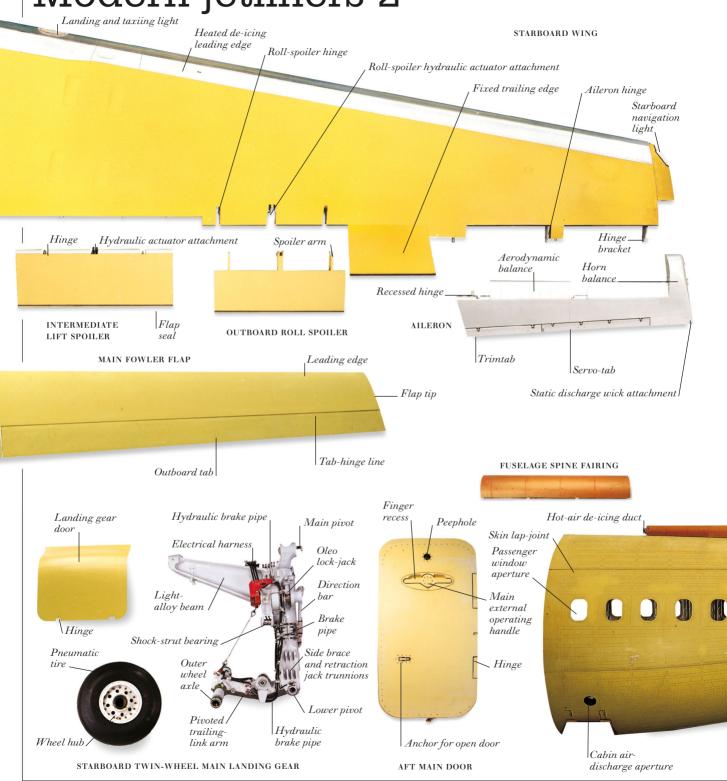
OF A BAE-146 JETLINER

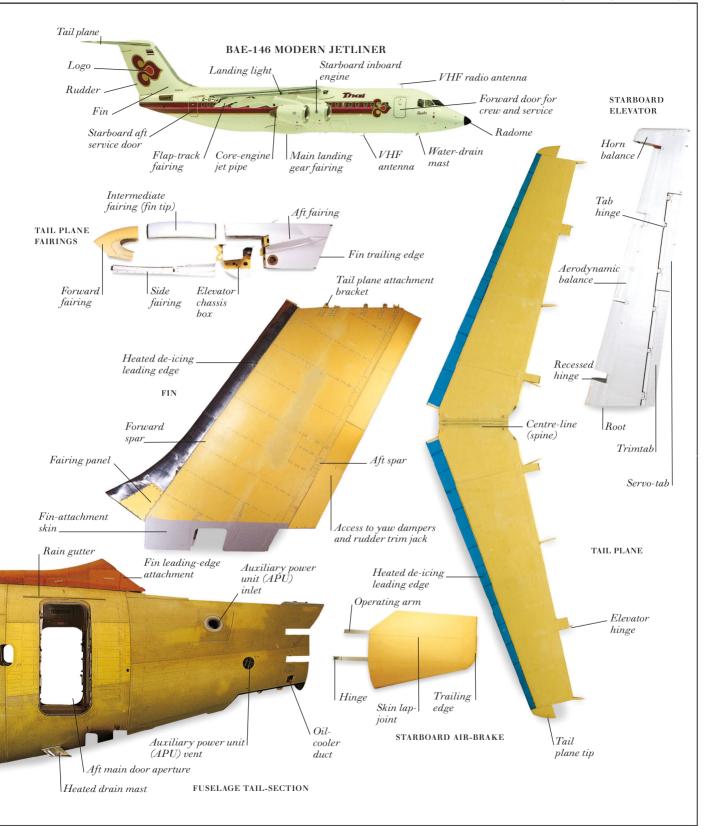




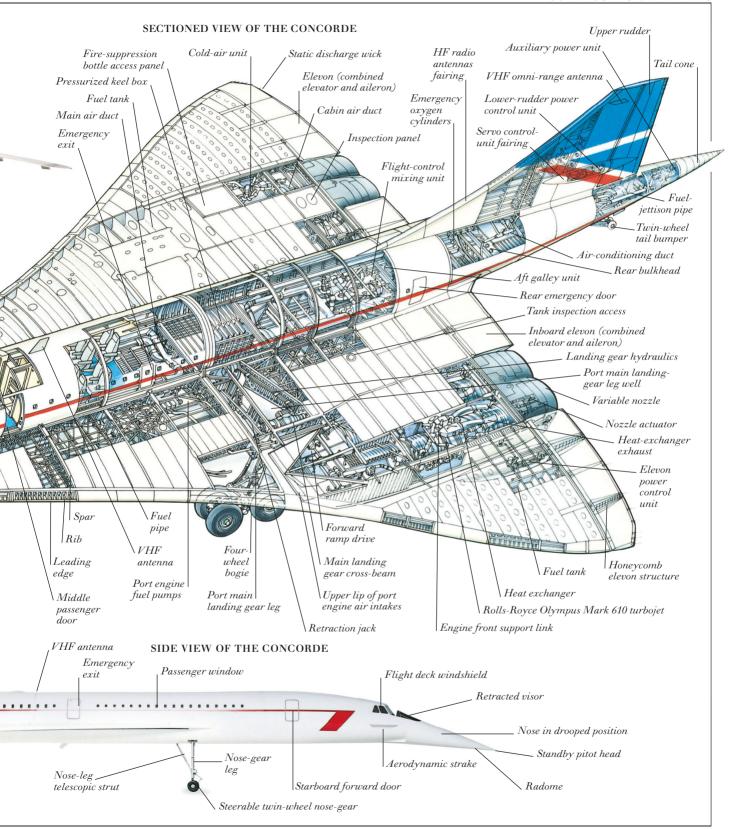


Modern jetliners 2

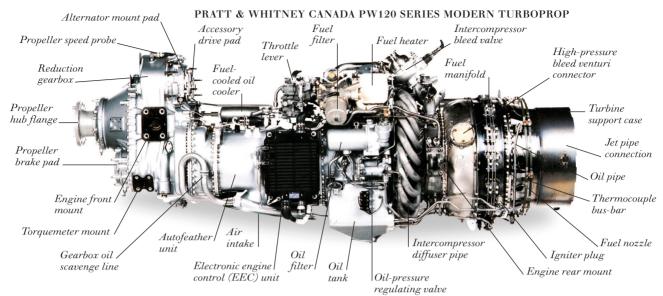


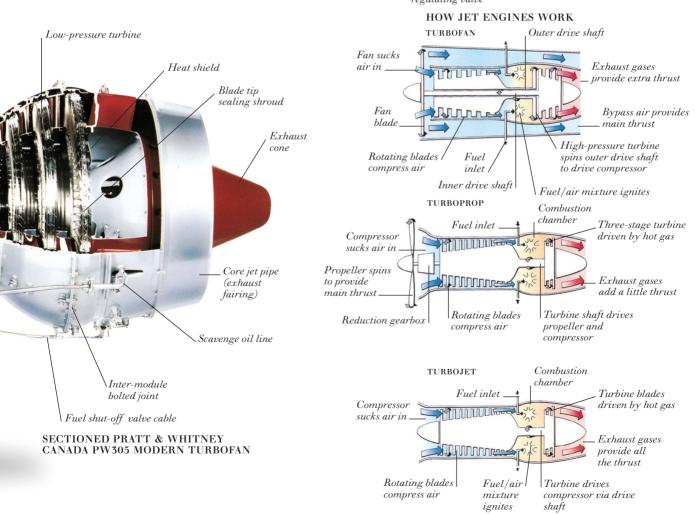


Supersonic jetliners Strake SUPERSONIC AIRCRAFT FLY FASTER than the speed of sound (Mach 1). There are many supersonic military aircraft, but only Standby two supersonic passenger-carrying aircraft (also called SSTs, or pitot head supersonic transports) have been produced: the Russian Tu-144, and the Concorde, produced jointly by Britain and France. The Tu-144 was withdrawn in 1978, COMPUTER-DESIGNED SST after only seven months in service. The Concorde remained in service from 1976 until 2003, with a Inhoard. Starboard. gear elevonbreak for modifications from July 2000 until October 2001. Its outboard leg iack features included a droop nose, which lowered during takeoff engine air-intake fairing and landing to aid visibility from the cockpit; the pumping of fuel between forward FRONT OF THE CONCORDE and aft trim tanks helped stabilize the aircraft. The Concorde had a narrow fuselage Toilets and shortspan wings to reduce drag during supersonic flight. Its noisy turbojet engines **Electrothermal** with afterburners enabled it to carry 100 passengers at a cruising speed of Mach 2 deicing panel at 50,000-60,000 ft (15,000-18,000 m). Once an aircraft is flying faster than Mach 1, Starboard it produces a continuous air-pressure wave, which is heard as a "sonic boom." forward trim tank Overhead luggage bin OVERHEAD VIEW OF Passenger THE CONCORDE Underfloor airaccommodation conditioning duct Seat attachment Life raft VHFWardrobe antenna Variable Leading edge nozzle Forward galley Additional crew's seat Aluminium-alloy layers Third pilot's and insulation Erosion-Cockpit resistant windshield radome Lateral bracing strut Telescopic strut Port Retractable Nose forward Steering gear trim tank Plug-type "A" frame leg actuator passenger Standby door Nose-gear Machined flight-control doorMulti-ply skin panel hydraulic jack high-pressure Captain's FinUpper, seat Weather rudder Dorsal fin radar Droop-Cockpit air-Emergency exit conditioning Visor jack nose hinge duct Pivoted Tail cone retractable frame Aft door Elevon (combined elevator and aileron) Hot-section steel and titanium skin Landing gear door. Engine cowling Bogie main landing gear



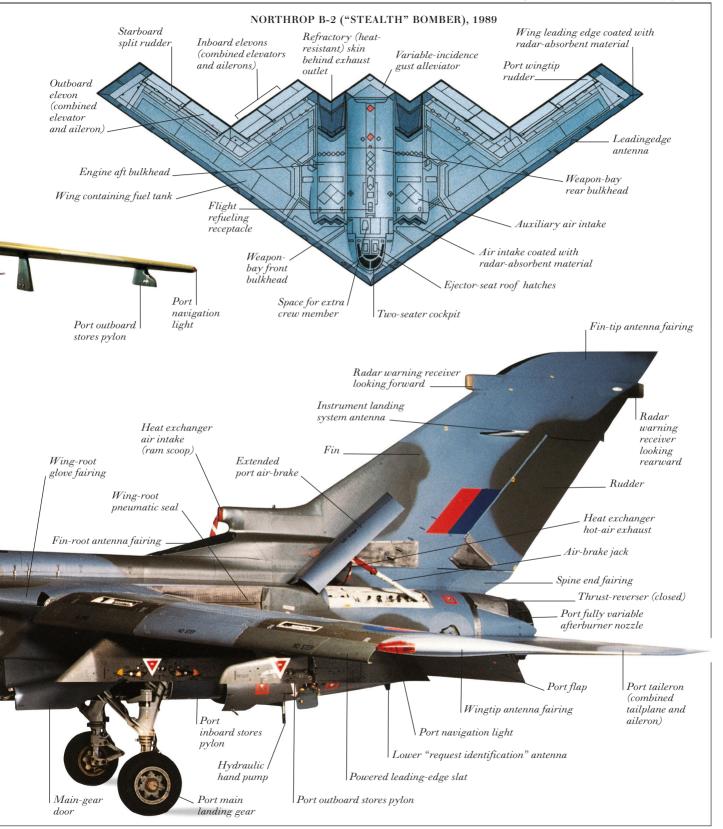
NPT 301 MODERN TURBOJET Jet engines Fuel sprayer Reverse-flow Radial diffuser combustion Turbine rotor chamber Centrifugal JET ENGINES ARE USED BY MOST MILITARY and heavy Exhaust diffuser compressor aircraft, and by many helicopters. The simplest type InducerTail cone Airof jet engine, or gas turbine, is the turbojet. It works by Jet pipe intake continuously burning a mixture of fuel and air in a combustion chamber to produce a jet of Exhaust hot exhaust gas that is expelled through a nozzle to produce thrust. The hot gas also spins Nose turbine blades, which, in turn, spin the blades of Alternator cone *Igniter* an air compressor; the compressor forces air into the combustion chamber. Many of the fastest aircraft use turbojets, Air impingement Nozzle guide vane starter with additional booster units called afterburners, but their use is Combustion chamber casing restricted by their high noise emission. Most jetliners use turbofan jet engines, which are quieter. An enormous fan, driven by a low-Combustion pressure turbine, feeds some air into the compressor but High-pressure chamber Gearbox feeds most of it through bypass ducts to Plenum ring for compressor Highbevel drive pressure hot anti-icing air Integral Fuel join the exhaust jetstream in the tail manifold . turbine Flow splitter cone. The bypass stream produces tank Fuel nozzle most of the thrust. Many Centrifugal smaller, propellercompressor driven aircraft use turboprop jet engines, in which the engine powers a propeller. *Temperature* and pressure sensor Low-pressure fan Inlet cone (rotating spinner) Pressure line Fan case with special structure to contain broken fan Electronic engine control and airframe interface connector Fan duct Electronic engine control (EEC) unit. Compressor air-Oil filter Compressor front bearing Engine front . Electrical Fuel and oil bleed connection mount wiring harness heat exchanger





Modern military aircraft

FRONT VIEW OF A Modern military aircraft are among the most sophisticated and expensive PANAVIA TORNADO products of the 21st century. Fighters need computer-operated controls for maneuverability, powerful engines, and effective air-to-air weapons. Most modern Instrument landing system fighters also have guided missiles, radar, and passive, infrared sensors. These antenna developments enable today's fighters to engage in combat with adversaries that are outside visual range. Bombers carry a large weapon load and enough Birdproof fuel for long-range flights. A few military aircraft, such as the Tornado and Port variablewindshield. incidence the F-14 Tomcat, have variable-sweep ("swing") wings. During takeoff Air data air intake and landing their wings are fully extended, but for high-speed probe Wing-root flight and low-level attacks the wings are pivoted fully back. A glove fairing recent development is the "stealth" bomber, which is designed to absorb or deflect enemy radar in order to remain undetected. Earlier bombers, such as the Tornado, use terrain-following radars to fly so close to Starboard the ground that they avoid enemy radar detection. inhoard. Taileron stores pylon Starboard main landing gear door Wing extended Wing pivoted Main landing gear leg for takeoff and back for highspeed flight landing containing Laser ranger and ground-mapping. marked-target seeker attack, and terrainfollowing radars Starboard nose gear door Steerable twin-wheel nose gear Taxiing light SWING-WING F-14 TOMCAT FIGHTER Navigator's Single canopy over both Pilot's cockpit cockpits SIDE VIEW OF A PANAVIA TORNADO GR1A cockpit Navigator's Engine air intake (RECONNAISSANCE VERSION), 1986 instrument console Navigation light Flat, birdproof windshield High-velocity air duct to disperse rain Upper "request identification" antenna Air data probe Radome containing ground-mapping, Hinged auxiliary UHF antenna attack, and terrainair intake Nose gear following radars Angle-of-attack probe door Cold air intake (ram scoop) Tacan (tactical air navigation) antenna Steerable Heat exchanger exhaust duct nose gear leg TwinEmergency canopy release handle Window covering infrared reconnaissance camera wheel

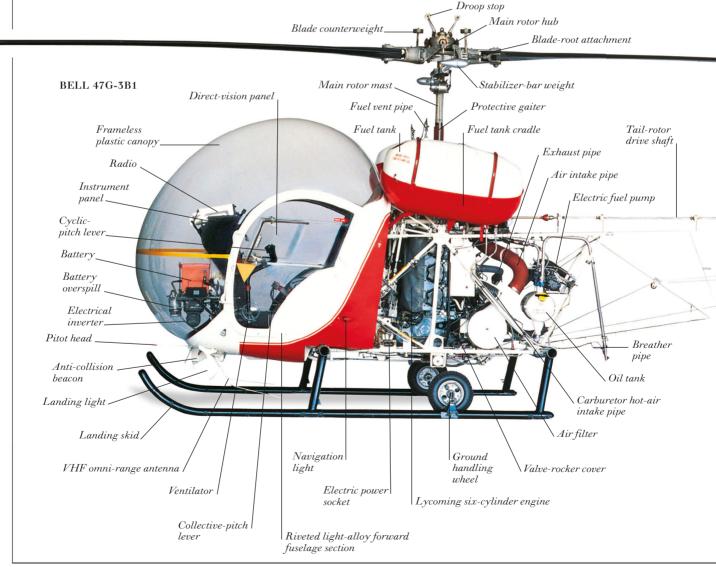


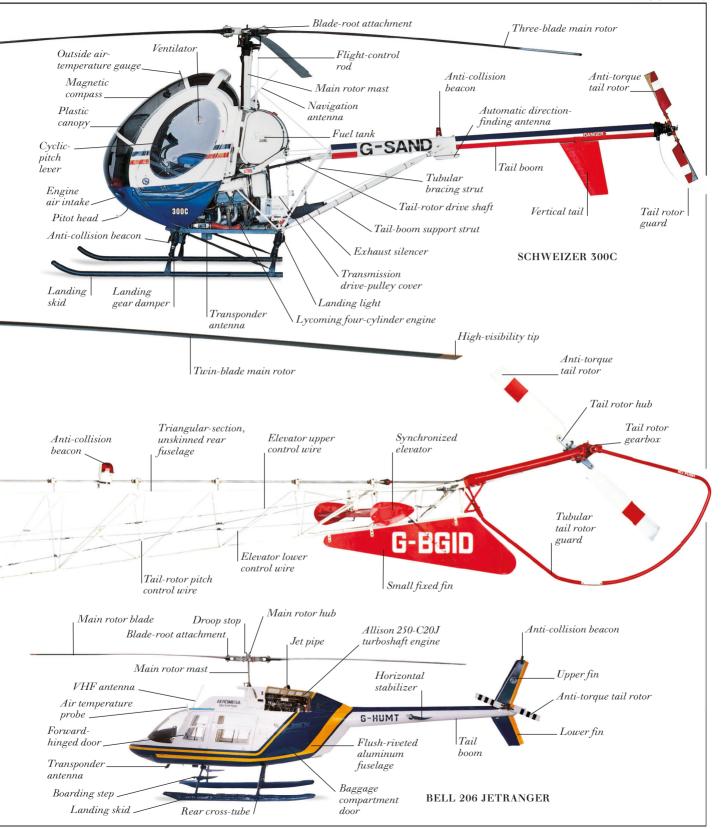
BELL 47G-3B1

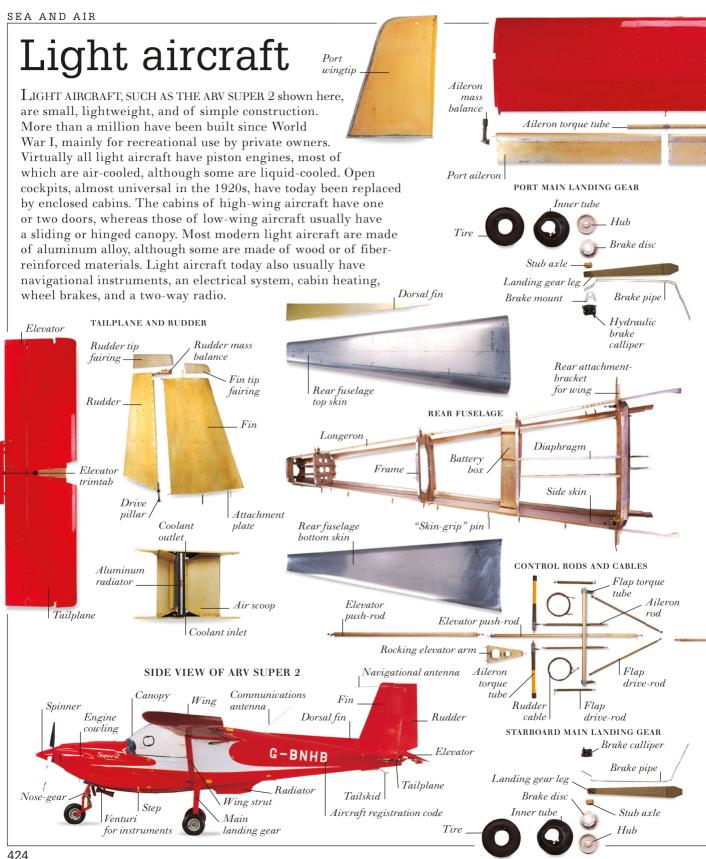
Helicopters

Helicopters USE rotating blades for lift, propulsion, and steering. The first machine to achieve sustained, controlled flight using rotating blades was the autogiro built in the 1920s by the Spaniard Juan de la Cierva. His machine had unpowered blades above the fuselage that relied on the flow of air to rotate them and provide lift as the autogiro was driven forward by a conventional propeller. Then, in 1939, the Russian-born American Igor Sikorsky produced his VS-300, the forerunner of modern helicopters. Its engine-driven blades provided lift, propulsion, and steering. It could take off vertically, hover, and fly in any direction, and had a tail rotor to prevent the helicopter body from spinning. The introduction of gas turbine jet engines to helicopters in 1955 produced quieter, safer, and more powerful machines. Because of their versatility in flight,

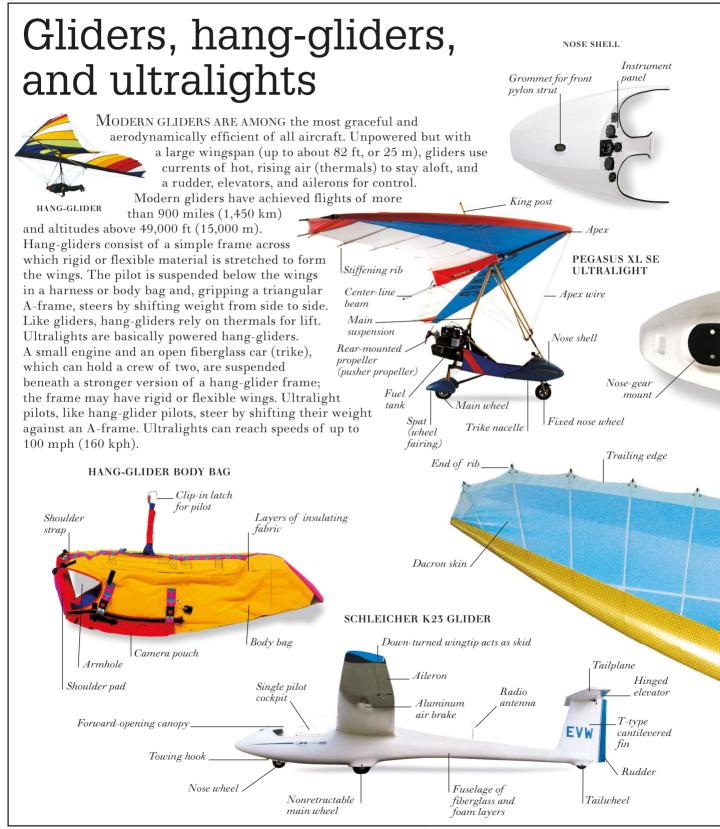
helicopters are today used for many purposes, including crop spraying, traffic surveillance, and transporting crews to deep-sea oil rigs, as well as acting as gunships, air ambulances, and air taxis.

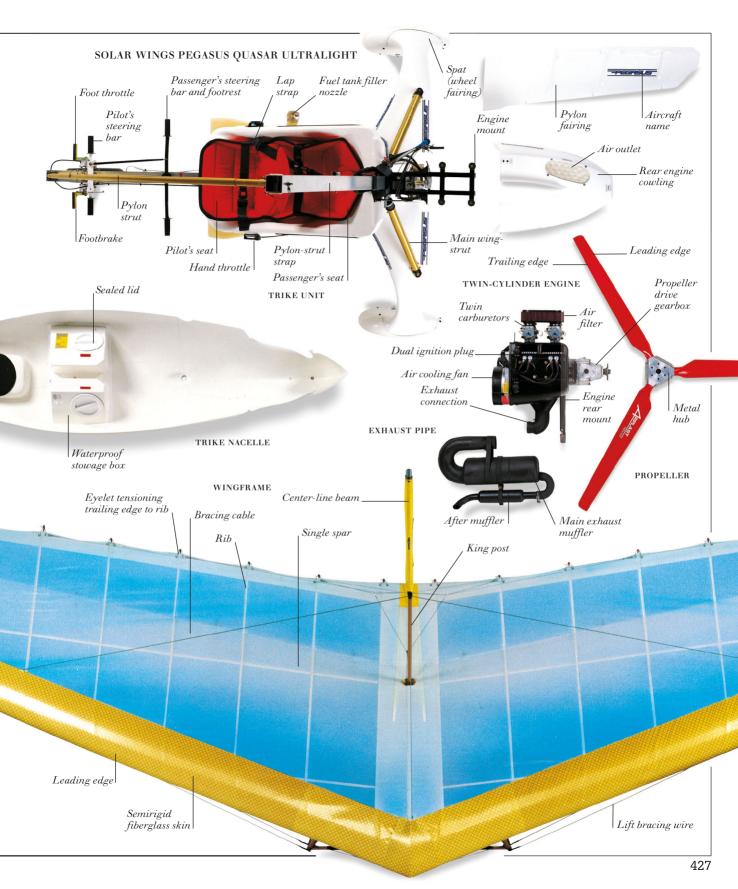












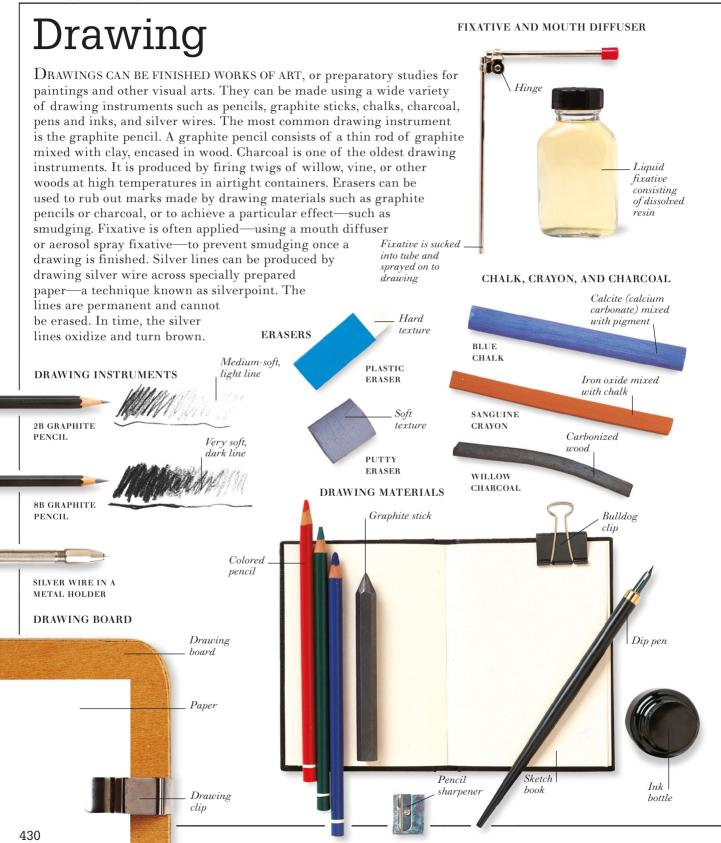


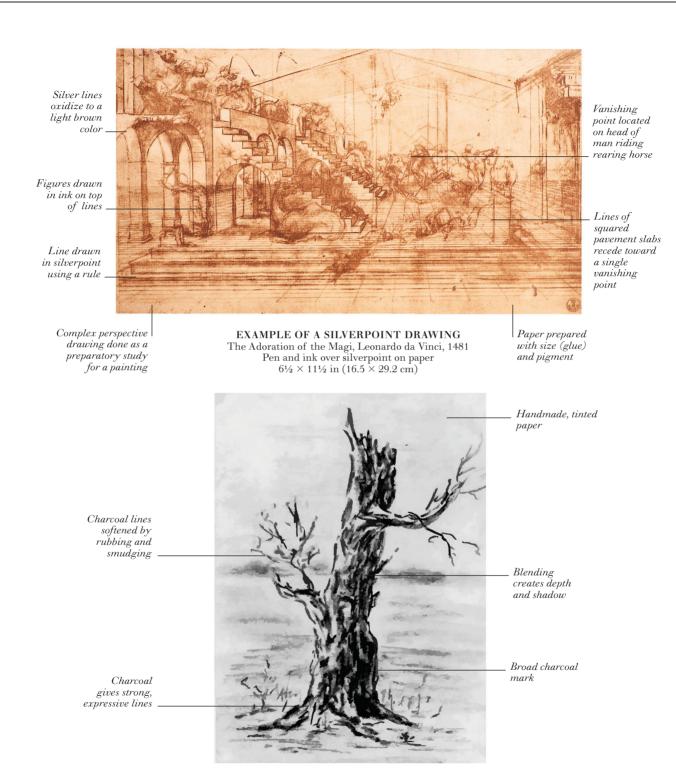


THE VISUAL ARTS

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EXAMPLE OF A CHARCOAL DRAWING Charcoal on paper

Tempera



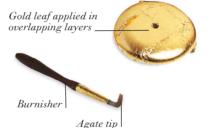
ILLUMINATED MANUSCRIPT

THE TERM TEMPERA is applied to any paint in which pigment is tempered (mixed) with a water-based binding medium—usually egg volk. Egg tempera is applied to a smooth surface such as vellum (for illuminated manuscripts) or more commonly to hardwood panels prepared with gesso-a mixture of chalk and size

(glue). Hog hair brushes are used to apply the gesso. A layer of gesso grosso (coarse gesso) is followed by successive layers of gesso sotile (fine gesso) that are sanded between coats to provide a smooth, yet absorbent ground. The paint is applied with fine sable brushes in thin layers, using light brushstrokes. Tempera dries quickly to form a tough skin with a satin sheen. The luminous white surface of the gesso combined with the overlaid paint produces the brilliant crispness and rich colors particular to this medium. Egg tempera paintings are frequently gilded with gold. Leaves of finely beaten gold are applied to a bole (reddishbrown clay) base and polished by burnishing.

Parchment for Brush protecting gold leaf from drafts Bowlcontaining diluted bole Gold leaf Gilder's knife Gilder's tip for picking up gold leaf Gilder's cushion

MATERIALS FOR GILDING



Gold leaf smoothed and

polisheď with a burnisher



Surface

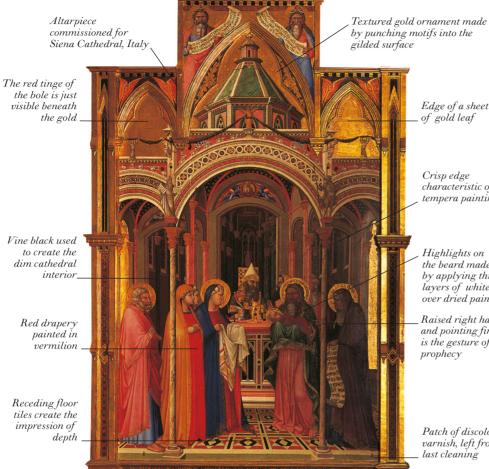
prepared with gesso

MATERIALS FOR TEMPERA PANEL PAINTING



EXAMPLE OF A TEMPERA PAINTING

Presentation in the Temple, Ambrogio Lorenzetti, 1342 Tempera on wood, 8 ft $5\frac{1}{8}$ in \times 5 ft $6\frac{1}{8}$ in (257 \times 168 cm)



FLESH-COLOR PAINTING



PIGMENTS FOR

VERDACCIO



VERMILION AND LEAD WHITE



VERMILION



varnish, left from last cleaning

Patch of discolored

Edge of a sheet

of gold leaf

Crisp edge characteristic of tempera painting

Highlights on

the beard made

by applying thin layers of white over dried paint Raised right hand

and pointing finger

is the gesture of

prophecy



RED EARTH (IRON OXIDE)



MALACHITE



VINE BLACK



EXAMPLES OF PIGMENTS

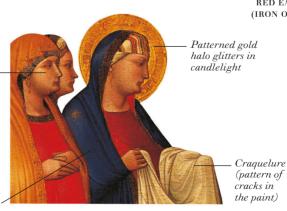
ULTRAMARINE LAPIS LAZULI



LEAD TIN YELLOW

Warm flesh tones achieved by layering vermilion and white over an undercoat of verdaccio

Ultramarine lapis lazuli, as costly as gold, was reserved for significant figures such as the Virgin Mary

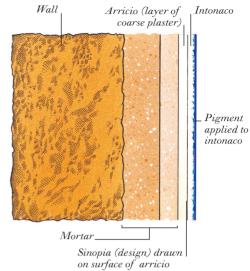


DETAIL FROM "PRESENTATION IN THE TEMPLE"

Fresco

CROSS-SECTION SHOWING FRESCO LAYERS

Fresco Is a Method of Wall Painting. In buon fresco (true fresco), pigments are mixed with water and applied to an intonaco (layer of fresh, damp lime-plaster). The intonaco absorbs and binds the pigments as it dries making the picture a permanent part of the wall surface. The intonaco is applied in sections called giornate (daily sections). The size of each giornata depends on the artist's estimate of how much can be painted before the plaster sets. The junctions between giornate are sometimes visible on a finished fresco. The range of colors used in buon fresco are limited to lime-resistant pigments such as earth colors (below). Slaked lime (burnt lime mixed with water), bianco di San Giovanni (slaked lime that has been partly exposed to air), and chalk can be used to produce fresco whites. In fresco secco (dry fresco), pigments are mixed with a binding medium and applied to dry plaster. The pigments are not completely absorbed into the plaster and may flake off over time.



EXAMPLES OF EARTH COLOR PIGMENTS



EXAMPLE OF A FRESCO

The Expulsion of the Merchants from the Temple, Giotto, c.1306 Fresco, $78 \times 72 \text{ in } (200 \times 185 \text{ cm})$

Temple acts as a backdrop for the action Bianco di San Giovanni often used for fresco whites

Gold leaf applied to apostle's halo

Green earth pigment applied to robe

> Child painted on top of apostle's robe



Azurite blue applied in fresco secco has flaked off to reveal the plaster beneath

Dry, matte surface characteristic of buon fresco

Artist has to finish giornata

Paint applied in buon fresco to child's face

White dove represents the Holy Ghost

> Paint applied in fresco secco to child's body has flaked off.



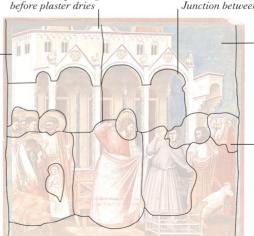
DETAIL FROM "THE

EXPULSION"

sketched in red earth

A fresco was generally worked in zones from the top down

Sinopia (design)



GIORNATE (DAILY SECTIONS) IN "THE EXPULSION"

One of a series of frescoes in the Arena Chapel, Padua, Italy

Patches of azurite blue have turned green due to reaction with carbon dioxide

Hairline junction between giornate is visible

Red earth pigment applied in buon fresco has retained rich hue

Junction between giornate

Area with little detail can be painted quickly, allowing a larger giornata to be completed

Highly detailed area takes a longer time to paint, restricting the size of the giornata

PALETTE

LINSEED OIL

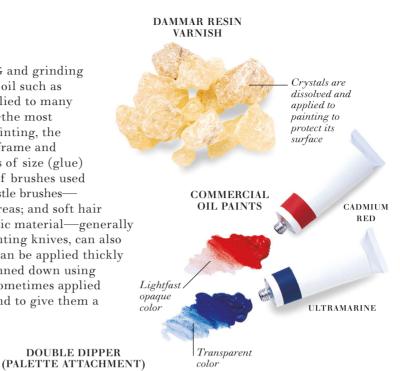
KIDNEY-SHAPED

OIL PAINTS ARE MADE BY MIXING and grinding pigment with a drying vegetable oil such as linseed oil. The paint can be applied to many different surfaces and textures—the most common being canvas. Before painting, the canvas is stretched on a wooden frame and its surface is prepared with layers of size (glue) and primer. The two main types of brushes used in oil painting are stiff hog hair bristle brushes generally used for covering large areas; and soft hair brushes made from sable or synthetic material—generally

used for fine detail. Other tools, including painting knives, can also be used to achieve different effects. Oil paint can be applied thickly (a technique known as impasto), or can be thinned down using a solvent—such as turpentine. Varnishes are sometimes applied to finished paintings to protect their surface and to give them a

matte or gloss finish.

EXAMPLES





EXAMPLE OF AN OIL PAINTING

Fritillarias, Vincent van Gogh, 1886 Oil on canvas, 29×24 in $(73.5 \times 60.5 \text{ cm})$



438

Watercolor

Watercolor Paint is made of ground pigment mixed with a watersoluble binding medium, usually gum arabic. It is usually applied to paper using soft hair brushes such as sable, goat hair, squirrel, and synthetic brushes. Watercolors are often diluted and applied as overlaying washes (thin, transparent layers) to build up depth of color. Washes can be laid in a variety of ways to create a range of different effects. For example, a wet-in-wet wash can be achieved by laying a wash on top of another wet wash. The two washes blend together to give a fused effect. Sponges are used to modify washes by soaking up paint so that areas of pigment are lightened or removed from the paper. Watercolors can also be applied undiluted—a technique known as dry brush—to create a broken-color effect. Watercolors are generally transparent and allow light to reflect from the surface of the paper through the layers of paint to give a luminous effect. They can be thickened and made opaque

GUM ARABIC

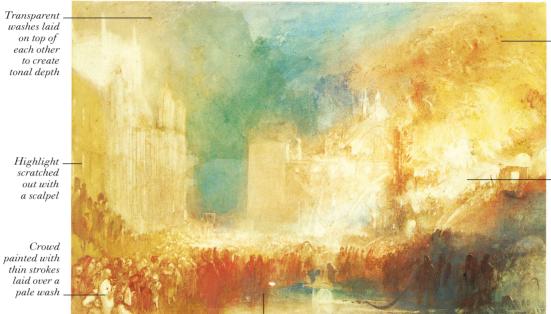


NATURAL SPONGE



EXAMPLE OF A WATERCOLOR

Burning of the Houses of Parliament, Turner, 1834 Watercolor on paper, $11\frac{1}{2} \times 17\frac{1}{2}$ in $(29.2 \times 44.5 \text{ cm})$



Transparent washes allow light to reflect off the surface of the paper to give a luminous effect

Paper shows through thin wash to give flames added highlight

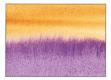
SMOOTH-

TEXTURED PAPER

Undiluted paint applied, then partly washed out, to create the impression of water

EXAMPLES OF WATERCOLOR PAPERS

WASH OVER DRY BRUSH Wash laid over paint applied with dry brush gives two-tone effect

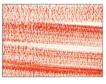


WET-IN-WET Two diluted washes left to run together to give fused effect

EXAMPLES OF WASHES



GRADED WASH Strong wash applied to tilted paper gives graded effect



DRY BRUSH Undiluted paint dragged across surface of paper gives broken effect

MEDIUM-TEXTURED

PAPER

ROUGH-TEXTURED

PAPER

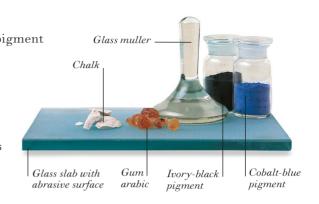
COLOR WHEEL OF WATERCOLOR PAINTS

Yellow (primary color) Secondary colours made by mixing yellow and blue Secondary colors made by mixing red and yellow Blue (primary color) Red (primary color) Secondary colors made by mixing blue and red

Pastels

PASTELS ARE STICKS OF PIGMENT made by mixing ground pigment with chalk and a binding medium, such as gum arabic. They vary in hardness depending on the proportion of the binding medium to the chalk. Soft pastel—the most common form of pastel—contains just enough binding medium to hold the pigment in stick form. Pastels can be applied directly to any support (surface) with sufficient tooth (texture). When a pastel is drawn over a textured surface, the pigment crumbles and lodges in the fibers of the support. Pastel marks have a particular soft, matte quality and are suitable for techniques such as blending, scumbling, and feathering. Blending is a technique of rubbing and fusing two or more colors on the support using fingers or various tools such as tortillons (paper stumps), soft hair brushes, putty erasers, and soft bread. Scumbling is a technique of building up layers of pastel colors. The side or blunted tip of a soft pastel is lightly drawn over an underpainted area so that patches of the color beneath show through. Feathering is a technique of applying parallel strokes of color with the point of a pastel, usually over an existing layer of pastel color. A thin spray of fixative can be applied using a mouth diffuser (see pp. 430-431) or aerosol spray fixative—to a finished pastel painting, or in between layers of color, to prevent smudging.

EQUIPMENT FOR MAKING PASTELS



EXAMPLES OF SOFT PASTELS

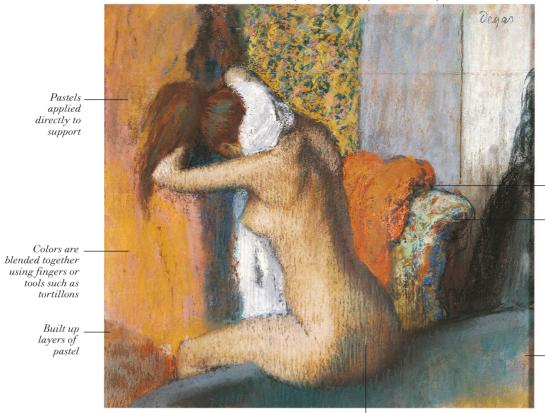




MAUVE FULL PASTEL



EXAMPLE OF A PASTEL PAINTING Woman Drying her Neck, Edgar Degas, c.1898 Pastel on cardboard, 24½ x 25½ in (62.5 x 65.5 cm)



Rich color of fabric created by overlaying yellows and oranges

Broken colors, characteristic $of\ scumbling$ technique

 $Toned\ color$ of paper visible beneath thinly applied pastels

Pure bright colors laid side by side produce strong contrasts

DETAIL FROM "WOMAN DRYING HER NECK"



EXAMPLES OF

COLORED AND

TINTED

PAPERS

Feathering technique used to produce skin tones

EXAMPLES OF TEXTURED PAPERS AND PASTEL BOARDS



WATERCOLOR PAPER (ROUGH TEXTURE)



INGRES PAPER



GLASS PAPER



FLOCKED PASTEL BOARD



WATERCOLOR PAPER (MEDIUM TEXTURE)

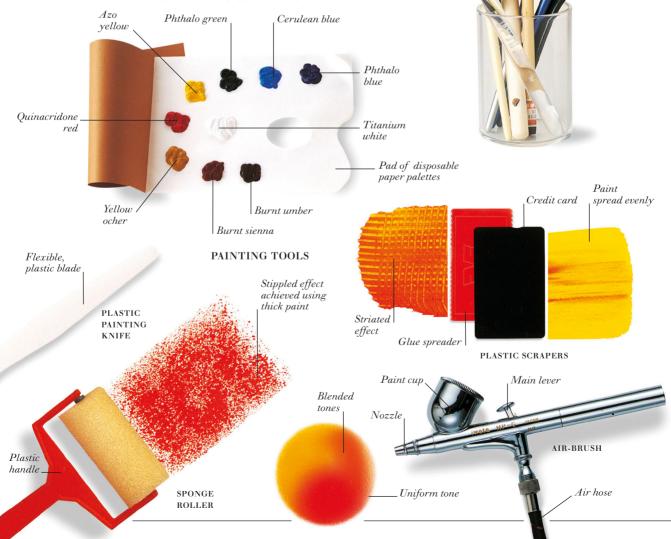


CANSON PAPER

Acrylics

ACRYLIC PAINT IS MADE BY MIXING PIGMENT with a synthetic resin. It can be thinned with water but dries to become water insoluble. Acrylics are applied to many surfaces, such as paper and acrylic-primed board and canvas. A variety of brushes, painting knives, rollers, air-brushes, plastic scrapers, and other tools are used in acrylic painting. The versatility of acrylics makes them suitable for a wide range of techniques. They can be used opaquely or—by Synthetic adding water—in a transparent, watercolor style. Acrylic wash mediums can be added to the paint to adjust its consistency brush for special effects such as glazing and impasto (ridges of paint applied in thick strokes) or to make it more matt or glossy. Acrylics are quick-drying, which allows layers of paint to be applied on top of each other almost immediately.

EXAMPLES OF PAINTS USED IN ACRYLICS



EXAMPLES OF BRUSHES

Synthetic hog

Synthetic

Ox hair

brush

sable brush.

ňair brush

Goat hair

brush

Hog hair

sash

brush

Sable

brush

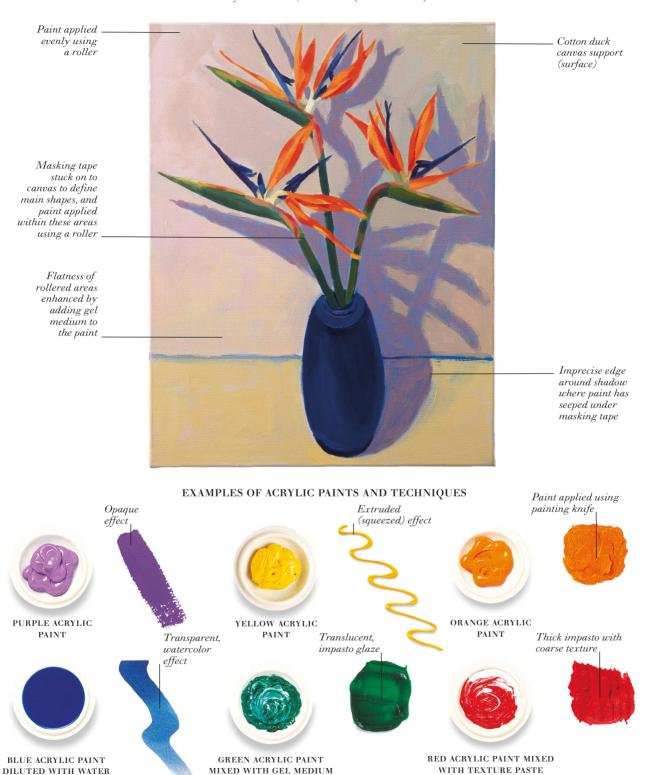
Hog

hair

brush

EXAMPLE OF AN ACRYLIC PAINTING

Acrylic on canvas, 8 x 10½ in (20.5 x 26.6 cm)



Calligraphy

CALLIGRAPHY IS BEAUTIFULLY FORMED LETTERING. The term applies to written text and illumination (the decoration of manuscripts using gold leaf and color). The essential materials needed to practice calligraphy are a writing tool, ink, and a writing surface. Quills are among the oldest writing tools. They are usually made from goose or turkey feathers, and are noted for their flexibility and ability to produce fine lines. A quill point, however, is not very durable and constant recutting and trimming is required. The most commonly used writing instrument in Western calligraphy is a detachable, metal nib held in a penholder. The metal nib is very durable, and there are a wide range of different types. Particular types of nibs—such as copperplate, speedball, and round-hand nibs—are used for specific styles of lettering. Some nibs have integral ink reservoirs and others have reservoirs that are detachable. Brushes are also used for writing, and for filling in outlined letters and painting decoration. Other writing tools used in calligraphy are fountain pens, felt-tip pens, rotring pens, and reed pens. Calligraphy inks may come in liquid form, or as a solid ink stick. Ink sticks are ground down in distilled water to form a liquid ink. The most common writing surfaces for calligraphy are good quality, smooth -surfaced papers. To achieve the best writing position, the calligrapher places the paper on a drawing board set at an angle.

EQUIPMENT USED IN BRUSH LETTERING

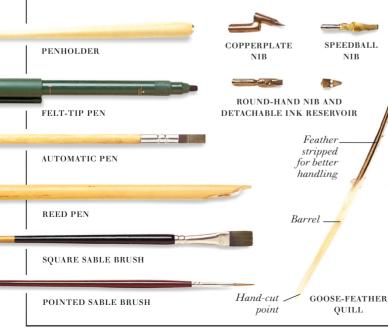




GOAT HAIR BRUSH

WOLF HAIR BRUSH

PENS, NIBS, AND BRUSHES USED IN CALLIGRAPHY



FOUNTAIN PEN AND INK

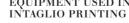


CHINESE LETTERING EXAMPLES OF LETTERING STYLES CurvedBowl Apexstroke StemRice paper Inner counter Counter Broad brush Crossbar Inner Counter Inner stroke counter counter Chinese ROMAN CAPITALS character meaning Curved long life Arch Ascender stroke EarCap line X lineBase line Descender Artist's stamped line signature Serif Descender ARTIST'S STAMP ITALIC ROMAN Height of letter determined by Stamp ladder of nib widths Stamped Slightly pinched Letter filled in signature (curved) vertical using brush of the artist stroke Ink pad Inner counter DRAWING BOARD TailPointed Spine apex VERSAL AN ILLUMINATED MANUSCRIPT Style of lettering called Gothic book script. ra hic midu mmilitabar. ma ofterunchaufumus di 11 on habitabir in medio comus es ma: Folfa mea liceennii azueri Decullus lum ur fenum Facuu ma que faor fupbiam: que loquet miqua i omtir melirmi odov mov ormam:quia oblinis fum com Enmatuano mifiadum omnos aac panan maun mine in organical and the contract of the cont Thor gaminis ma: aobairos omomnes opantes iniquitatemann cami mar. mit fre für elli cano folmiomis: Immertande Blade with Adjustable set Large decorative orám mama fumfiairmamarizomalio letter used to parallel motion Ligitaur facus fum ficur piffer square damormentae mark the Trumpar Tas folmanus in mno on attal fa ota dicerprobabant in immi opening of EXAMPLES OF ama: quilaudabantmeaduer a chapter CALLIGRAPHY PAPERS m mc iurabanr 🔯 🗷 🗷 🖎 Standard ua anon tanq° panč manduca Proti meti aum flatumiloba nquaaimq dic mnotaucon European paper _ Words written Indian handmade paper carefully by hand Flecked, tinted paper Gold leaf Grid lines provide *Imitation* guide to position of parchment paper _ words and pictures

Printmaking 1

PRINTS ARE MADE BY FOUR BASIC printing processes—intaglio, lithographic, relief, and screen. In intaglio printing, lines are engraved or etched into the surface of a metal plate. Lines are engraved by hand using sharp metal tools. They are etched by corroding the metal plate with acid, using acidresistant ground to protect the areas not to be etched. The plate is then inked and wiped, leaving the grooves filled with ink and the surface clean. Dampened paper is laid over the plate, and both paper and plate are passed through the rollers of an etching press. The pressure of the rollers forces the paper into the grooves, so that it takes up the ink, leaving an impression on the paper. Lithographic printing is based on the antipathy between grease and water. An image is drawn on a surface—usually a stone or metal plate—with a greasy medium, such as tusche (lihographic ink). The greasy drawing is fixed on to the plate by applying an acidic solution, such as gum arabic. The surface is then dampened and rolled with ink. The ink adheres only to the greasy areas and is repelled by the water. Paper is laid on the plate and pressure is applied by means of a press. In relief printing, the nonprinting areas of a wood or linoleum block are cut away using gouges, knives, and other tools. The printing areas are left raised in relief and are rolled with ink. Paper is laid on the inked block and pressure is applied by means of a press or by burnishing (rubbing) the back of the paper. The most common forms of relief printing are woodcut, wood engraving, and linocut. In screen printing, the printing surface is a mesh stretched across a wooden

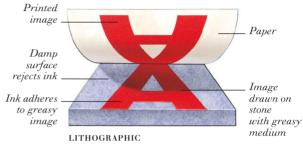
frame. A stencil is applied to the mesh to seal the nonprinting areas and ink is scraped through the mesh to produce an image.





THE FOUR MAIN PRINTING PROCESSES











SCRIBER

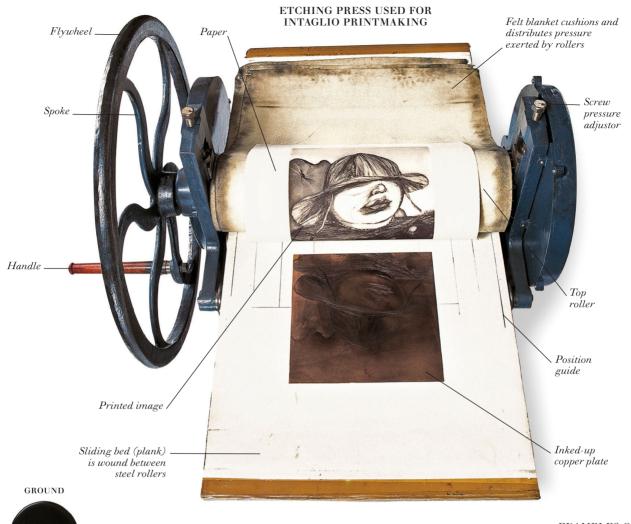
LEATHER

INK DABBER

ROULETTE

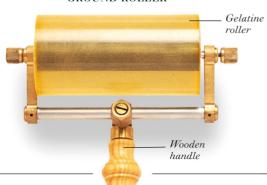
446

ROCKER



Acid-resistant ground rolled onto metal plate before etching

GROUND ROLLER





EXAMPLE OF AN INTAGLIO PRINT Annie with a Sun Hat, Jock McFadyen, 1993 Etched copper plate, $16\times15\%$ in $(41\times40~\text{cm})$

EXAMPLES OF PRINTING PAPERS



Printmaking 2

EXAMPLE OF A LITHOGRAPHIC STONE AND PRINT

Untitled, Frederic M. Pannebaker, 1972



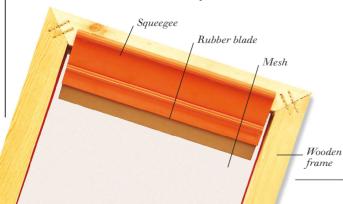
IMAGE DRAWN ON STONE

LITHOGRAPIC PRINT

EXAMPLE OF A SCREEN PRINT Patrons In An Art Deco Club, Unknown, 1931



SCREEN AND SQUEEGEE



EQUIPMENT USED IN LITHOGRAPHIC PRINTING

CRAYON AND HOLDER

LITHOGRAPHIC PENCIL

TUSCHE (LITHOGRAPHIC INK) PEN

ERASING STICK



EXPANDABLE SPONGE



TUSCHE (LITHOGRAPHIC INK) STICK



RUBBING INK







INK ROLLER

GUM ARABIC SOLUTION

WATER-BASED SCREEN PRINTING INKS



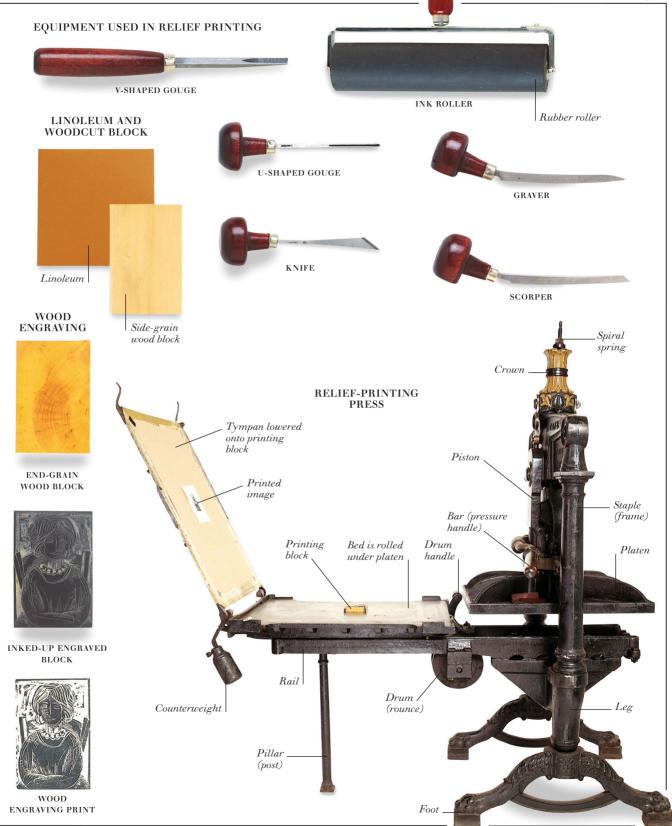
BLUE ACRYLIC INK



RED ACRYLIC INK

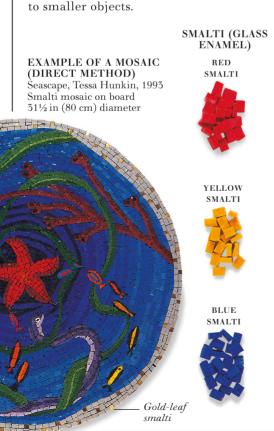


BROWN TEXTILE INK



Mosaic

MOSAIC IS THE ART OF MAKING patterns and pictures from tesserae (small, colored pieces of glass, marble, and other materials). Different materials are cut into tesserae using different tools. Smalti (glass enamel) and marble are cut into pieces using a hammer and a hardy (a pointed blade) embedded in a log. Vitreous glass is cut into pieces using a pair of pliers. Mosaics can be made using a direct or indirect method. In the direct method, the tesserae are laid directly into a bed of cement-based adhesive. In the indirect method, the design is drawn in reverse on paper or cloth. The tesserae are then stuck face-down on the paper or cloth using water-soluble glue. Adhesive is spread with a trowel on to a solid surface—such as a wall—and the back of the mosaic is laid into the adhesive. Finally, the paper or cloth is soaked off to reveal the mosaic. Gaps between tesserae can be filled with grout. Grout is forced into gaps by dragging a grouting squeegee across the face of the mosaic. Mosaics are usually used to decorate walls and floors, but they can also be applied



EQUIPMENT FOR BREAKING MARBLE



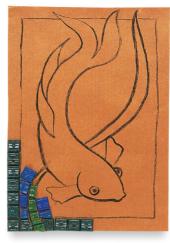
Wooden handle

STAGES IN THE CREATION OF A MOSAIC (INDIRECT METHOD)



COLOR SKETCH A color sketch is drawn in oil pastel to give a clear impression of how the finished mosaic will look.

shape with pliers



REVERSE IMAGE Tesserae are glued face-down on reverse image on paper. Mosaic is then attached to solid surface and paper is removed.

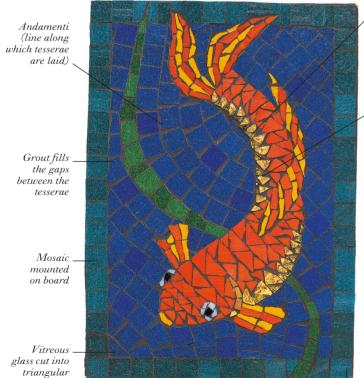


MOSAIC POT

MOSAIC MOSQUE DESIGN



Geometric border



FINISHED MOSAIC

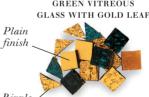
Goldfish, Tessa Hunkin, 1993

Vitreous glass mosaic on board $14 \times 10^{\circ}$ in $(35.5 \times 25.5 \text{ cm})$

Gold tessera placed upside down Plain

Gold tessera with ripple

finish



VITREOUS GLASS GREEN VITREOUS



RED VITREOUS GLASS

Ripple finish

SHEETS OF VITREOUS GLASS



GLASS

Border of square vitreous glass



Sculpture 1

THE TWO TRADITIONAL METHODS OF MAKING SCULPTURE are carving and modeling. A carved sculpture is made by cutting away the surplus from a block of hard material such as stone, marble, or wood. The tools used for carving vary according to the material being carved. Heavy steel points, claws, and chisels that are struck with a lump hammer are generally used for stone and marble. Sharp gouges and chisels that are struck with a wooden mallet are used for wood. Sculptures formed from hard materials are generally finished by filing with rasps, rifflers, and other abrasive implements. Modeling is a process by which shapes are built up, using malleable materials such as clay, plaster, and wax. The material is cut with wire-ended tools and modeled with the fingers or a variety of hardwood and metal implements. For large or intricate modeled sculptures an armature (frame), made from metal or wood, is used to provide internal support. Sculptures formed in soft materials may harden naturally or can be made more durable by firing in a kiln. Modeled sculptures are often first designed in wax or another material to be cast later in a metal (see pp. 454-455) such as bronze. The development of many new materials in the 20th century has enabled sculptors to experiment with new techniques such as construction (joining preformed pieces of material such as machine components, mirrors, and furniture) and kinetic (mobile) sculpture.

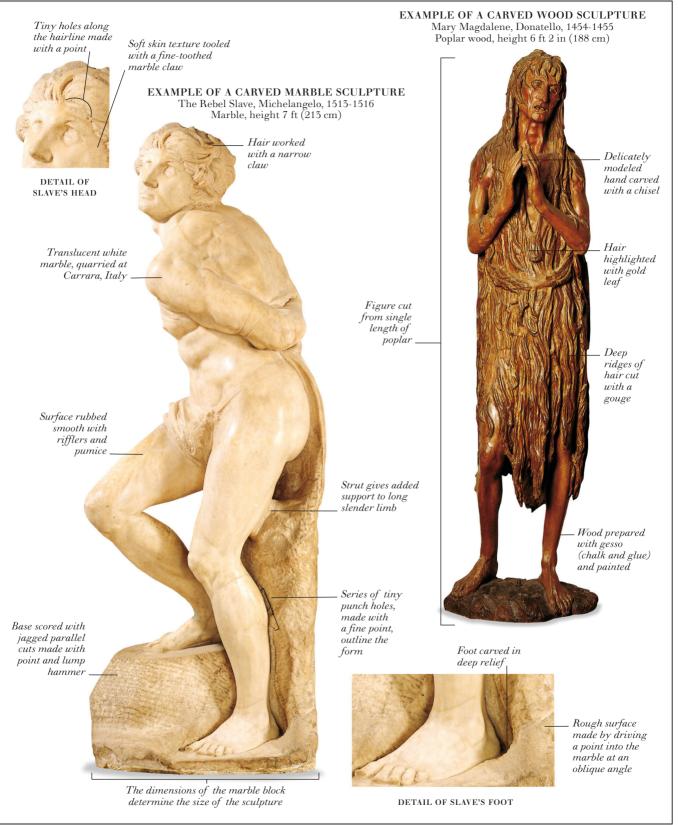
EXAMPLES OF MARBLE CARVING TOOLS 21/2 lb (1.1 kg)iron head Ashhandle LUMP HAMMER WIDE NARROW MARBLE MARBLE CLAW CLAW POINT FLAT CHISEL BULLNOSE CHISEL

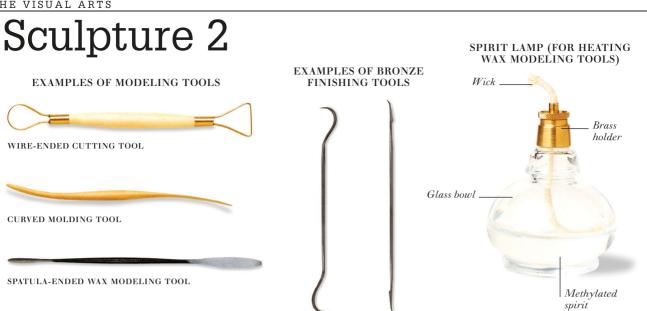


MALLET

452

CALLIPERS





HOOKED RIFFLER

POINTED

RIFFLER

STAGES IN THE LOST-WAX METHOD OF CASTING Based on Mars, Giambologna, c.1546



ROUNDED WAX MODELING TOOL

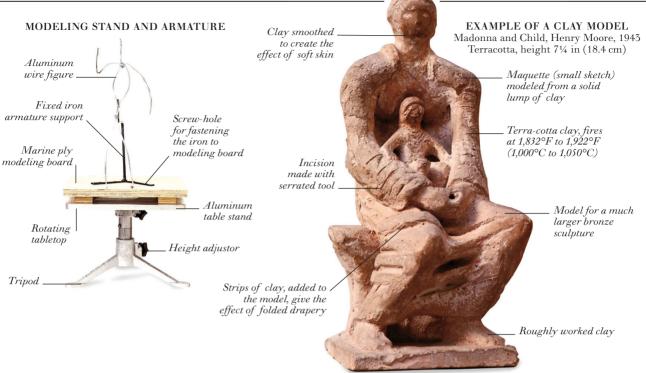
ORIGINAL MODEL An original, solid wax model is made and preserved so that numerous replicas can be cast.

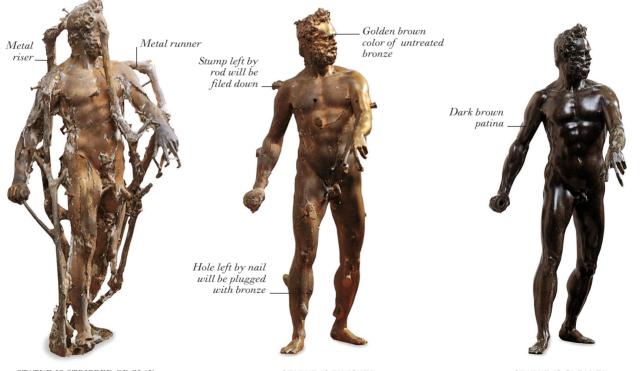


HOLLOW WAX FIGURE IS CAST A new, hollow wax model is cast from the original model. It is filled with a plaster core that is held in place with nails. Wax runners and risers are attached.



FIGURE IS BAKED IN CASTING MOLD The model is encased in clay and baked. The wax melts away (through the channels made by the wax rods) and is replaced by molten bronze.



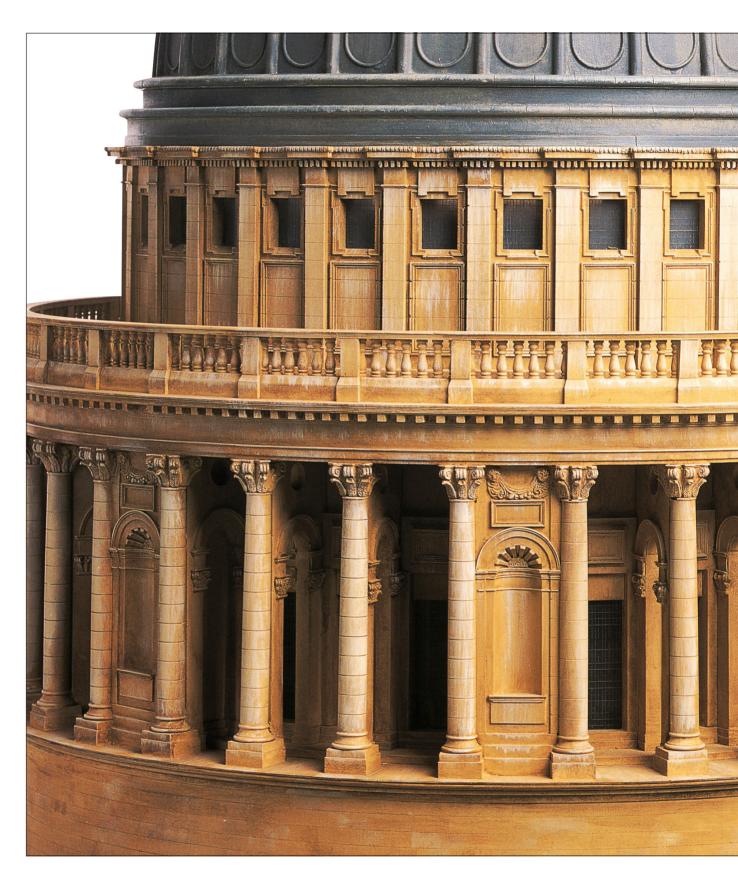


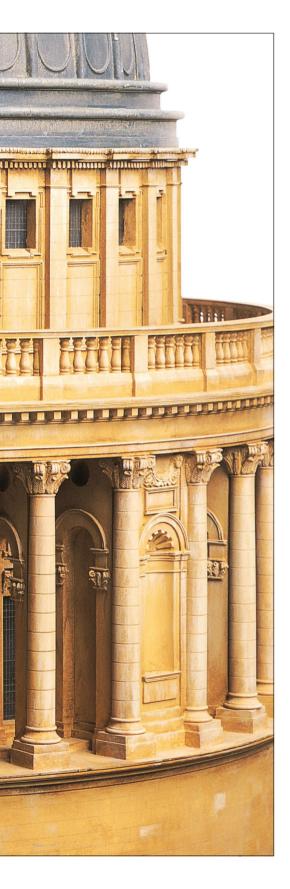
STATUE IS STRIPPED OF CLAY
When the bronze has cooled, the
clay mold is broken open to reveal
the bronze statue with solid metal
runners and risers.

STATUE IS FINISHED

The nails are pulled out and a large hole is made to remove the plaster core. When the metal rods have been sawn off, the sculpture is filed to refine the surface.

STATUE IS CLEANED
Finally, the work is cleaned and polished. An artificial patina (coloring) is achieved by treating the surface with chemicals.





ARCHITECTURE

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Ancient Egypt

tombs. Egyptian temples were often huge and geometric, like the Temple of Amon-Re (below and

Roman Empire in 30 BC) is famous for its temples and

right). They were usually decorated with hieroglyphs

reliefs depicting gods, Pharaohs (kings), and queens.

Tombs were particularly important to the Egyptians, who believed that the dead were resurrected in the

afterlife. The tombs were often decorated—as, for example, the surround of the false door opposite—in

order to give comfort to the dead. The best-known

ancient Egyptian tombs are the pyramids, which

were designed to symbolize the rays of the Sun. Many of the architectural forms used by the ancient Egyptians were later adopted by other civilizations; for example, columns and capitals were later used by the ancient Greeks (see pp. 460-461) and ancient Romans (see pp. 462-465). FRONT VIEW OF HYPOSTYLE HALL, TEMPLE OF AMON-RE

Cornice decorated with cavetto molding THE CIVILIZATION OF THE ANCIENT EGYPTIANS (which lasted Campaniform from about 3100 BC until it was finally absorbed into the (open papyrus) capital Architrave. (sacred characters used for picture-writing) and painted Papyrusbud capital Socle

Side aisle

Central nave

Architrave

Side aisle

Stone slab forming flat roof of side aisle

north-south

Horus, the Sun-god

SIDE VIEW OF HYPOSTYLE HALL, TEMPLE OF AMON-RE, KARNAK, EGYPT, c. 1290 BC

of the gods

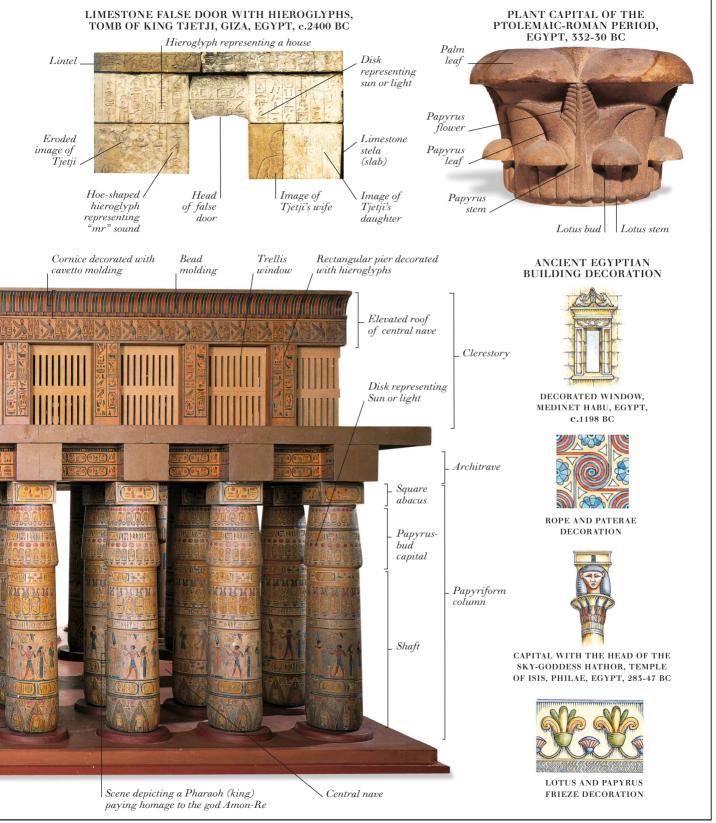
sky-goddess

motif



the titles of the Pharaoh (king)

Moon-god



Ancient Greece

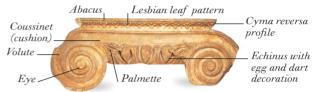
THE CLASSICAL TEMPLES OF ANCIENT GREECE were built according to the belief that certain forms and proportions were pleasing to the gods. There were three main ancient Greek architectural orders (styles), which can be distinguished by the decoration and proportions of their columns, capitals (column tops), and entablatures (structures resting on the capitals). The oldest is the Doric order, which dates from the seventh century BC and was used mainly on the Greek mainland and in the western colonies, such as Sicily and southern Italy. The Temple of Neptune, shown here, is a classic example of this order. It is hypaethral (roofless) and peripteral (surrounded by a single row of columns). About a century later, the more decorative Ionic order developed on the Aegean Islands. Features of this order include volutes (spiral scrolls) on capitals and acroteria (pediment ornaments). The Corinthian order was invented in Athens in the fifth century BC and is typically identified by an acanthus leaf on the capitals. This order was later widely used in ancient Roman architecture.

TEMPLE OF NEPTUNE, PAESTUM, ITALY, c.460 BC

CAPITALS OF THE THREE ORDERS OF ANCIENT GREEK ARCHITECTURE



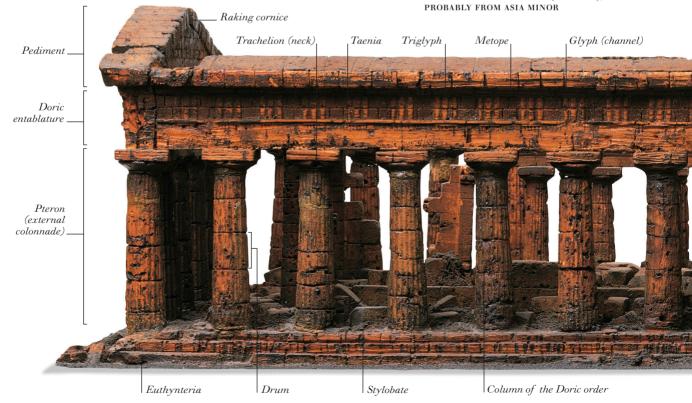
DORIC CAPITAL, THE PROPYLAEUM (GATEWAY), THE ACROPOLIS, ATHENS, GREECE, 449 BC



IONIC CAPITAL, THE PROPYLAEUM (GATEWAY), TEMPLE OF ATHENA POLIAS, PRIENE, GREECE, c.334 BC

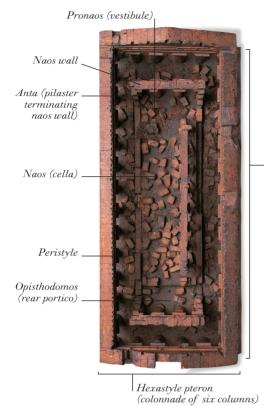


CORINTHIAN CAPITAL FROM A STOA (PORTICO),
PROBABLY FROM ASIA MINOR



PLAN OF THE TEMPLE OF NEPTUNE, PAESTUM

ANCIENT GREEK BUILDING DECORATION



Entasis (slight curve of a column)

. Pteron (external colonnade)



FACADE, TREASURY OF ATREUS, MYCENAE, GREECE, 1350-1250 BC



FRETWORK, PARTHENON, ATHENS, GREECE, 447-436 BC

Raking

cornice

Fluting

ACROTERION, TEMPLE OF APHAIA, AEGINA, GREECE, 490 BC

> Griffon / (gryphon)

ANTEFIXA, TEMPLE OF APHAIA, AEGINA, GREECE, 490 BC

Palmette
Volute

Regula (short fillet beneath taenia)

Cornice

Frieze

Architrave

Capital

Shaft

Crepidoma (stepped base)

Intercolumniation

461

Series of concentric.

Dentil ornament

Engaged pediment

Raking cornice

Pediment Rotunda

Entablature

Colonnade

Pitched roof

Eaves

steplike rings

Ancient Rome 1

IN THE EARLY PERIOD OF THE ROMAN EMPIRE extensive use was made of ancient Greek architectural ideas, particularly those of the Corinthian order (see pp. 460-461). As a result, many early Roman buildings—such as the Temple of Vesta (opposite)—closely resemble ancient Greek buildings. A distinctive Roman style began to evolve in the first century AD. This style developed the interiors of buildings (the Greeks had concentrated on the exterior) by using arches, vaults, and domes inside the buildings, and by ornamenting internal walls. Many of these features can be seen in the Pantheon. Exterior columns were often used for decorative, rather than structural. purposes, as in the Colosseum and the Porta Nigra (see pp. 464-465). Smaller buildings had timber frames with wattle-and-daub walls, as in the mill (see pp. 464-465). Roman architecture remained influential for many centuries, with some of its principles being used in the 11th century in Romanesque buildings (see pp. 468-469) and also in the 15th and 16th centuries in Renaissance buildings (see pp. 474-477).

Octastyle portico

FRONT VIEW OF THE PANTHEON

SIDE VIEW OF THE PANTHEON

Intermediate

Ornamental

with festoons

band decorated

(eight-column portico)

Upper

cornice

Attached

fluted pilaster

Outer saucer dome

Intermediate block

Entablature

inscription

Entablature

Curved

cornice

Lesene

Cornice

Concave

niche

Triangular pediment

Relieving arch

Opening for ventilation

Cornice

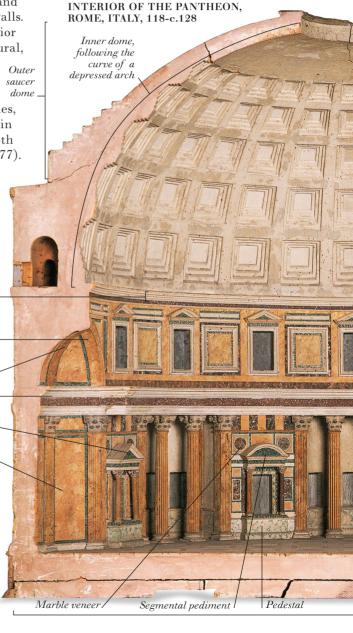
ANCIENT ROMAN BUILDING DECORATION



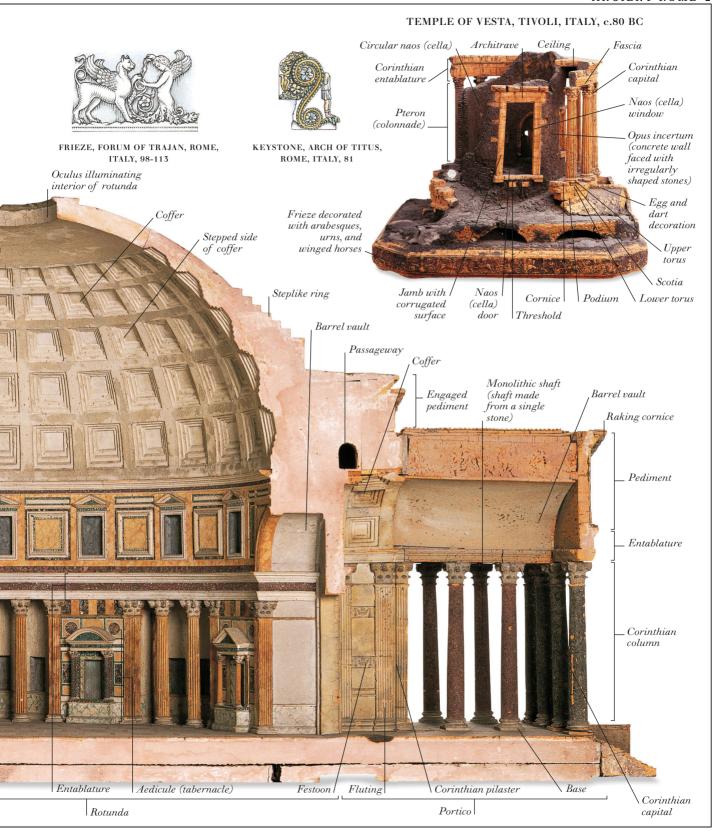


FESTOON, TEMPLE OF VESTA, TIVOLI, ITALY, C.80 BC

RICHLY DECORATED ROMAN OVUM

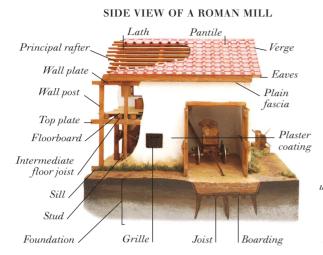


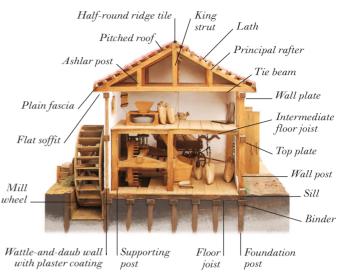




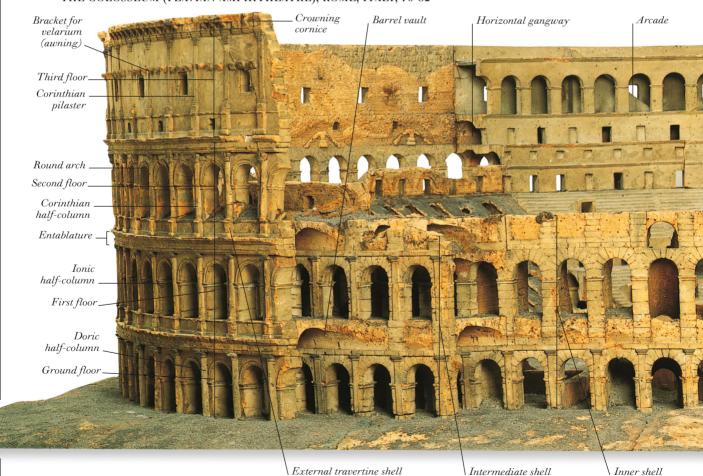
Ancient Rome 2

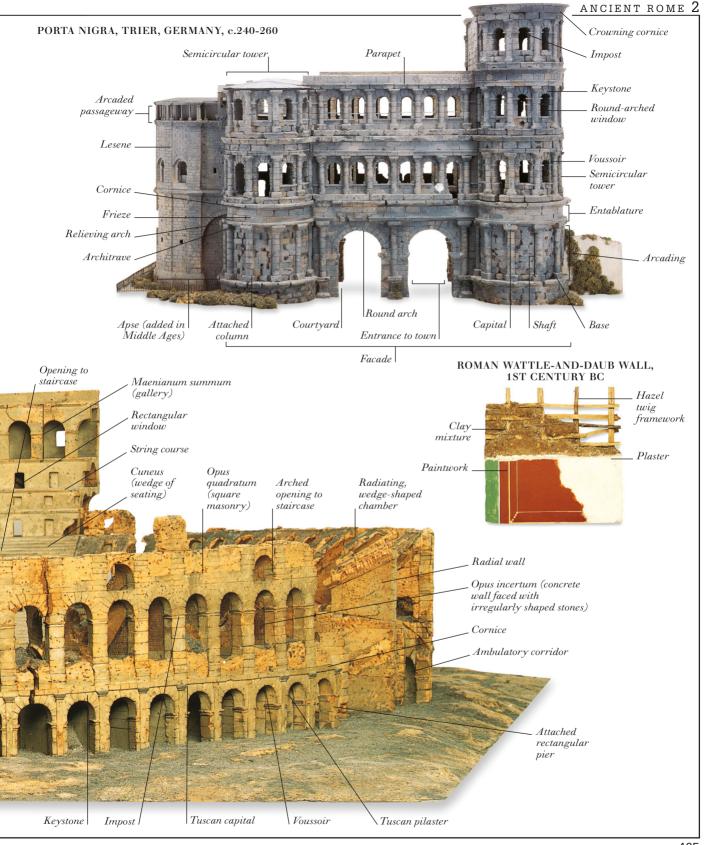
FRONT VIEW OF A ROMAN MILL, 1ST CENTURY BC





THE COLOSSEUM (FLAVIAN AMPHITHEATRE), ROME, ITALY, 70-82





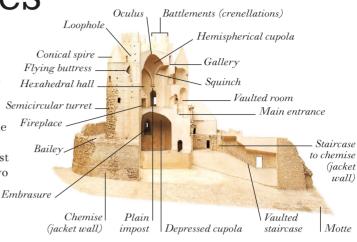
Medieval castles and houses

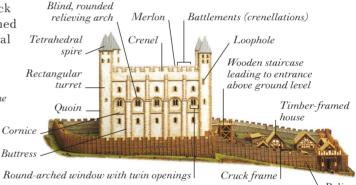
Warfare was common in Europe in the Middle Ages, and many monarchs and nobles built castles as a form of defense. Typical medieval castles have outer walls surrounding a moat. Inside the moat is a bailey (courtyard), protected by a chemise (jacket wall). The innermost and strongest part of a medieval castle is the keep. There are two main types of keep: towers called donjons, such as the Tour de César and Coucy-le-Château, and rectangular keeps ("hall-keeps"), such as the Tower of London. Castles were often guarded by salients (projecting fortifications), like those of the Bastille. Medieval houses typically had timber cruck (tentlike) frames, wattle-and-daub walls, and pitched



roofs, like those on medieval

DONJON, TOUR DE CESAR, PROVINS. FRANCE, 12TH CENTURY





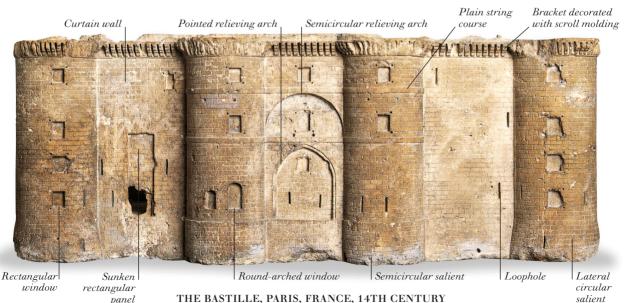
SALIENT, CAERNARVON CASTLE, BRITAIN, 1283-1323

panel

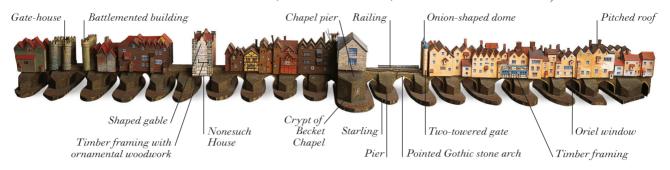
CRUCK-FRAMED HOUSE, BRITAIN, c.1200

TOWER OF LONDON, BRITAIN, FROM 1070

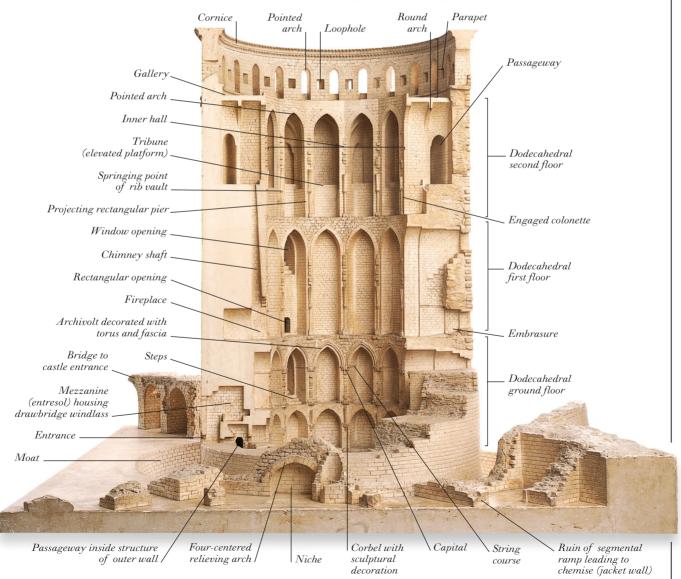
salient

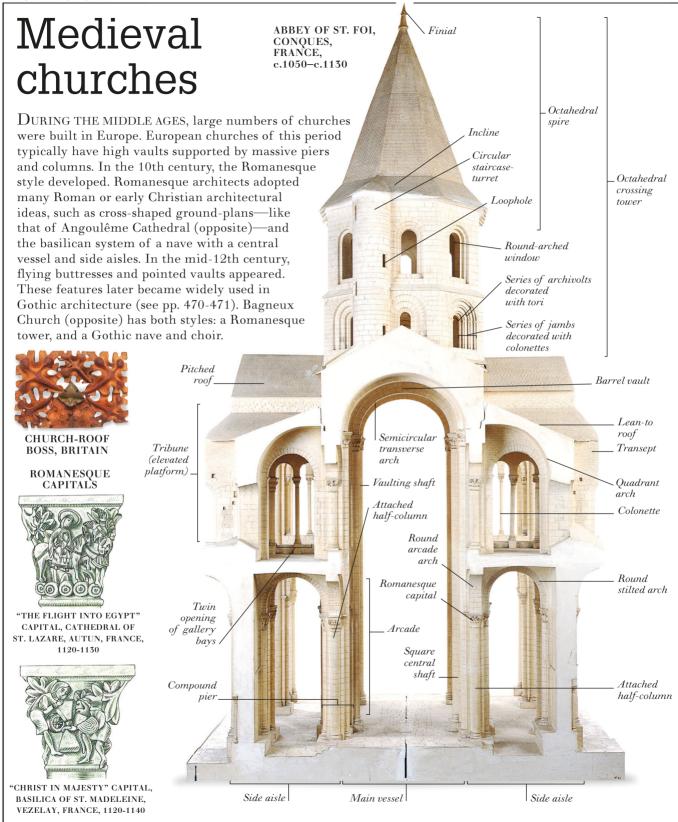


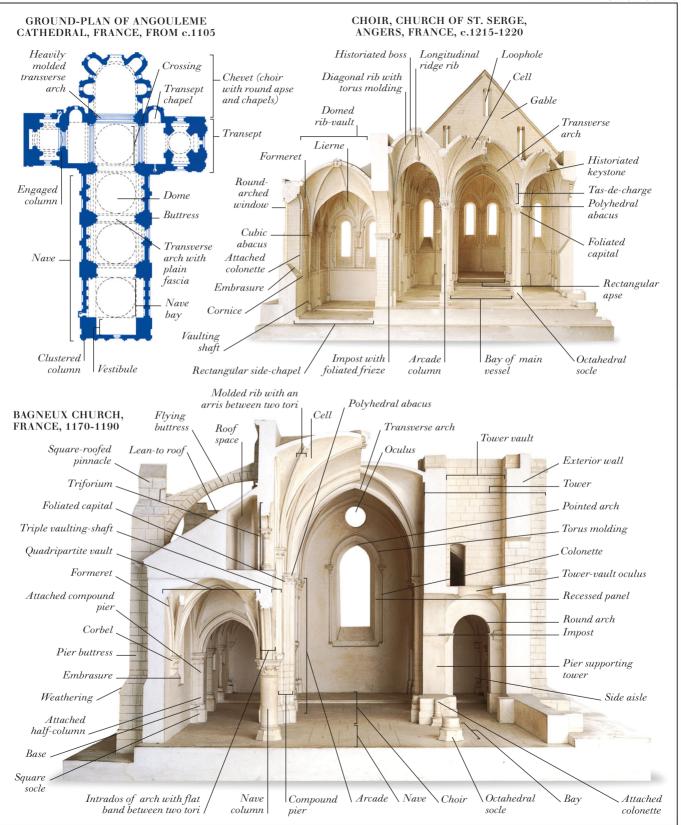
MEDIEVAL LONDON BRIDGE, BRITAIN, 1176 (WITH 14TH-CENTURY BATTLEMENTED BUILDING, NONESUCH HOUSE, AND TWO-TOWERED GATE)



DONJON, COUCY-LE-CHATEAU, AISNE, FRANCE, 1225-1245







Gothic 1

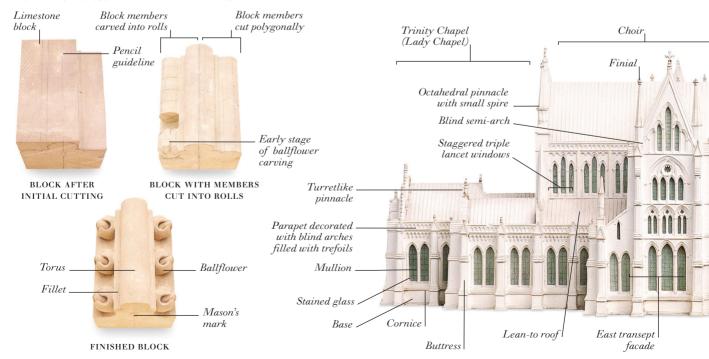


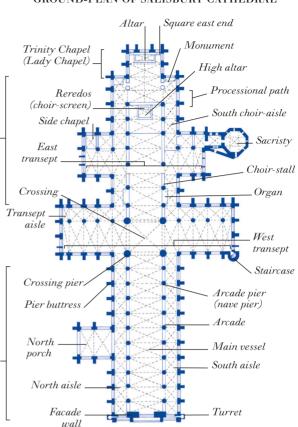
GOTHIC STAINED GLASS WITH FOLIATED SCROLL MOTIF, ON WOODEN FORM

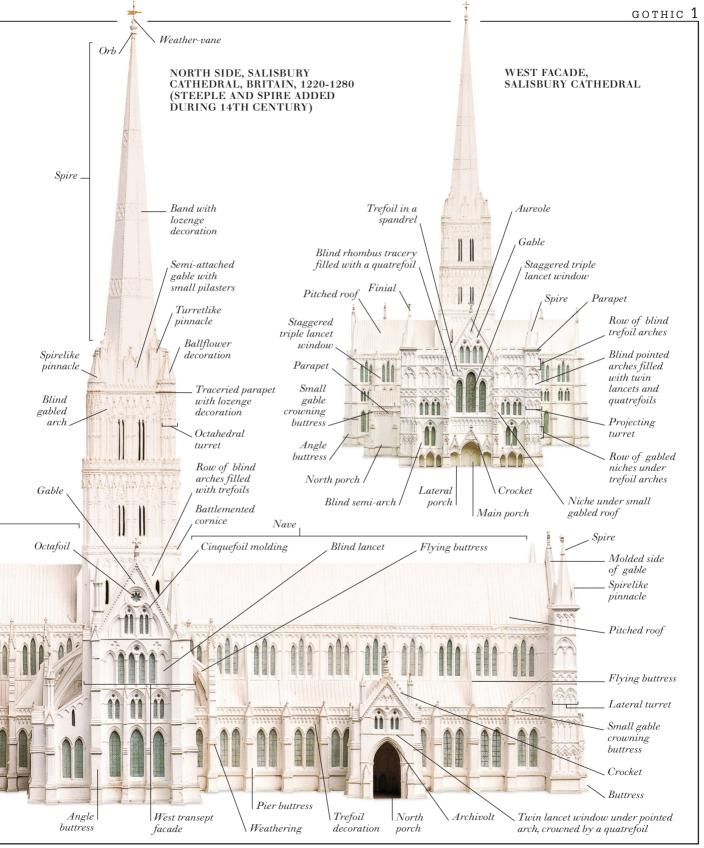
GOTHIC BUILDINGS are characterized by rib vaults, pointed or lancet arches, flying buttresses, decorative tracery and gables, and stained-glass windows. Typical Gothic buildings include the Cathedrals of Salisbury and old St. Paul's in England, and Notre Choir-Dame de Paris in France (see pp. 472-473). The Gothic style developed out of Romanesque architecture in France (see pp. 468-469) in the mid-

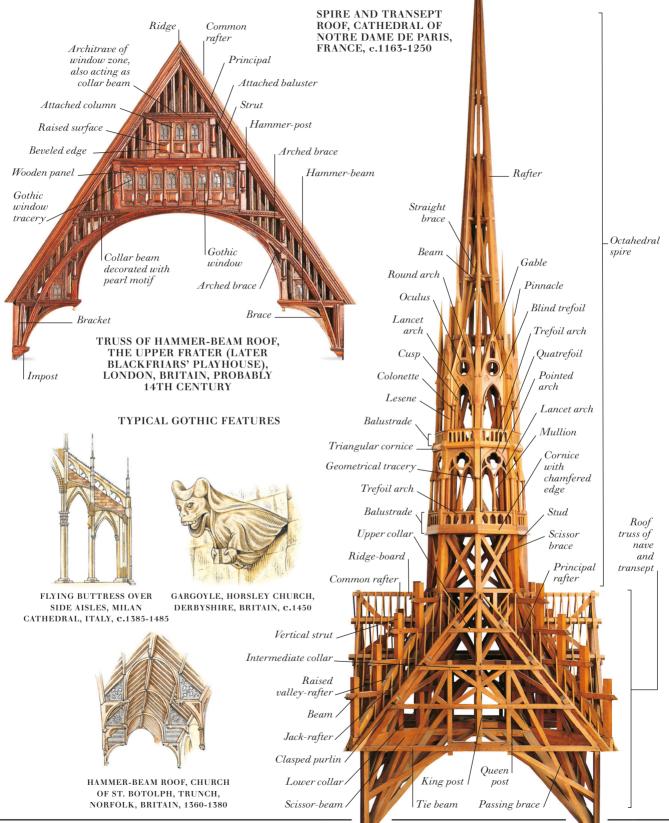
12th century, and then spread throughout Europe. The decorative elements of Gothic architecture became highly developed in buildings of the English Decorated style (late 13th-14th century) and the French Flamboyant style (15th-16th century). These styles are exemplified by the tower of Salisbury Cathedral and the staircase in the Church of St. Maclou (see pp. 472-473), respectively. In both of these styles, embellishments such as ballflowers and curvilinear (flowing) tracery were used liberally. The English Perpendicular style (late 14th-15th century), which followed the Decorated style, emphasized the vertical and horizontal elements of a building. A notable feature of this style is the hammer-beam roof.

GOTHIC TORUS WITH BALLFLOWERS





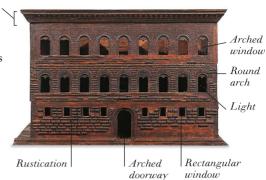


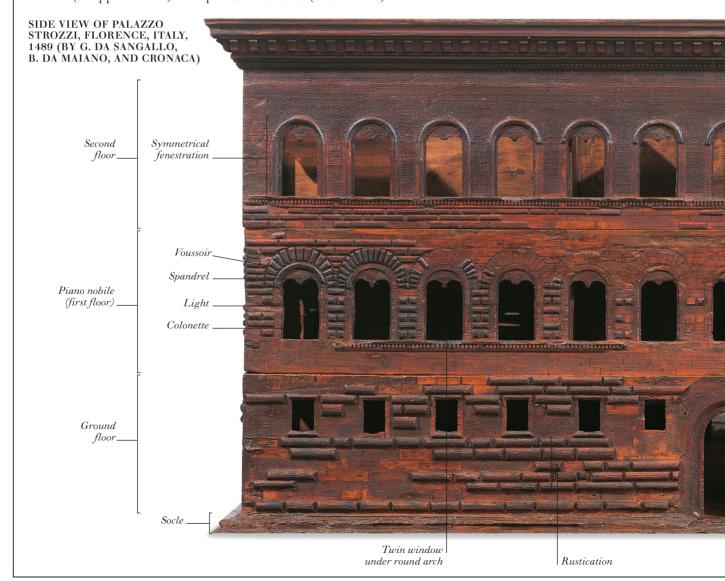


FACADE ON TO PIAZZA, PALAZZO STROZZI

Renaissance 1

THE RENAISSANCE was a European movement—lasting roughly from the 14th century to the mid-17th century—in which the arts and sciences underwent great changes. In architecture, these changes were marked by a return to the classical forms and proportions of ancient Roman buildings. The Renaissance originated in Italy, and the buildings most characteristic of its style can be found there, such as the Palazzo Strozzi shown here. Mannerism is a branch of the Renaissance style that distorts the classical forms; an example is the Laurentian Library staircase. As the Renaissance style spread to other European countries, many of its features were incorporated into the local architecture; for example, the Château de Montal in France (see pp. 476-477) incorporates aedicules (tabernacles).





Crowning cornice

DETAILS FROM ITALIAN RENAISSANCE BUILDINGS



PANEL FROM DRUM OF DOME, FLORENCE CATHEDRAL, 1420-1436



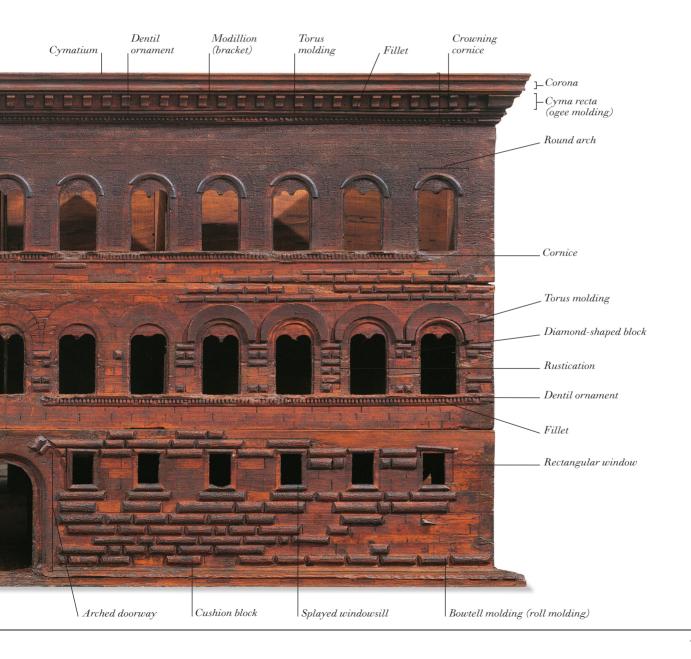
COFFERING IN DOME, PAZZI CHAPEL, FLORENCE, 1429-1461

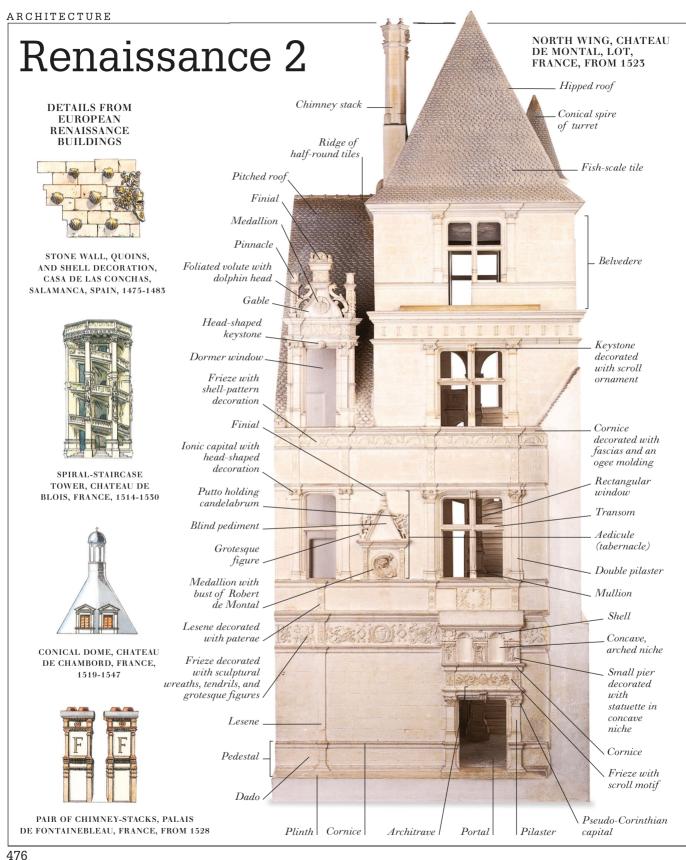


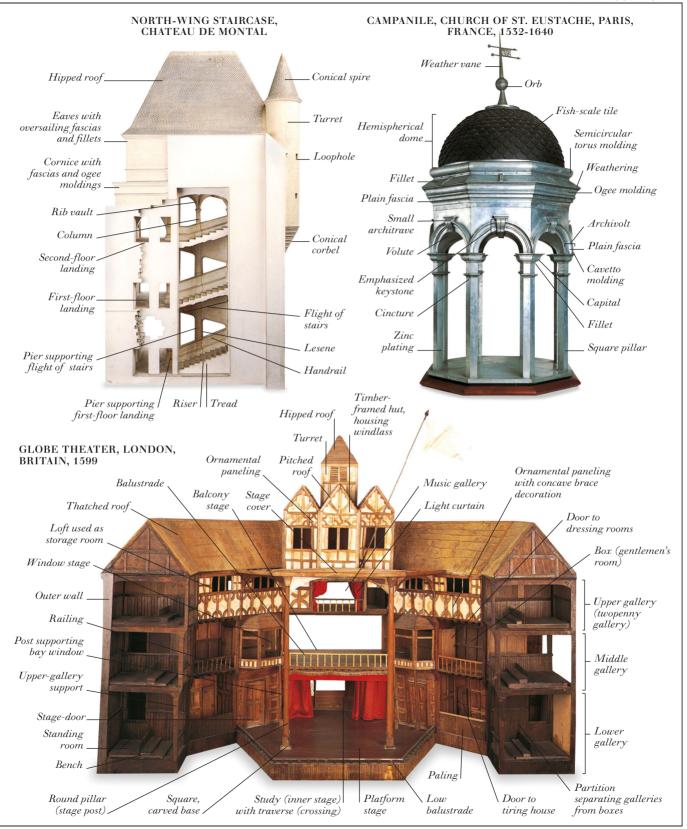
STAIRCASE, LAURENTIAN LIBRARY, FLORENCE, 1559



PORTICO, VILLA ROTUNDA, VICENZA, 1567-1569







Baroque and neoclassical 1

THE BAROQUE STYLE EVOLVED IN THE EARLY 17TH CENTURY in Rome. It is characterized by curved outlines and ostentatious decoration, as can be seen in the Italian church details (right). The baroque style was particularly widely favored in Italy, Spain, and Germany. It was also adopted in Britain and France, but with adaptations. The British architects Sir Christopher Wren and Nicholas Hawksmoor, for example, used baroque features—such as the concave walls of St. Paul's Cathedral and the curved buttresses of the Church of St. George in the East (see pp. 480-481)—but they did so with restraint. Similarly, the curved buttresses and volutes of the Parisian Church of St. Paul-St. Louis are relatively plain. In the second half of the 17th century, a distinct classical style (known as neoclassicism) developed in northern Europe as a reaction to the excesses of baroque. Typical of this new style were churches such as the Madeleine (a proposed facade is shown below), as well as secular buildings such as the Cirque Napoleon (opposite) and the buildings of the British architect Sir John Soane (see pp. 482-483). In early 18th-century France, an extremely lavish form of baroque developed, known as rococo. The balcony from Nantes (see pp. 482-483) with its twisted ironwork and head-shaped corbels is typical of this style. Attached segmental pediment



DETAILS FROM ITALIAN

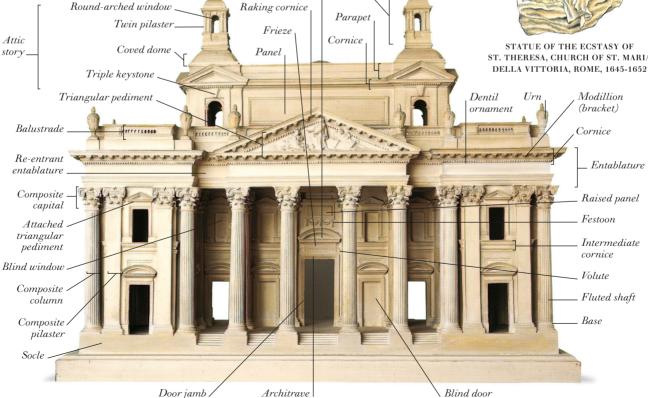
BAROQUE CHURCHES

CHURCH OF ST. MARIA DELLA **SALUTE, VENICE, 1631-1682**



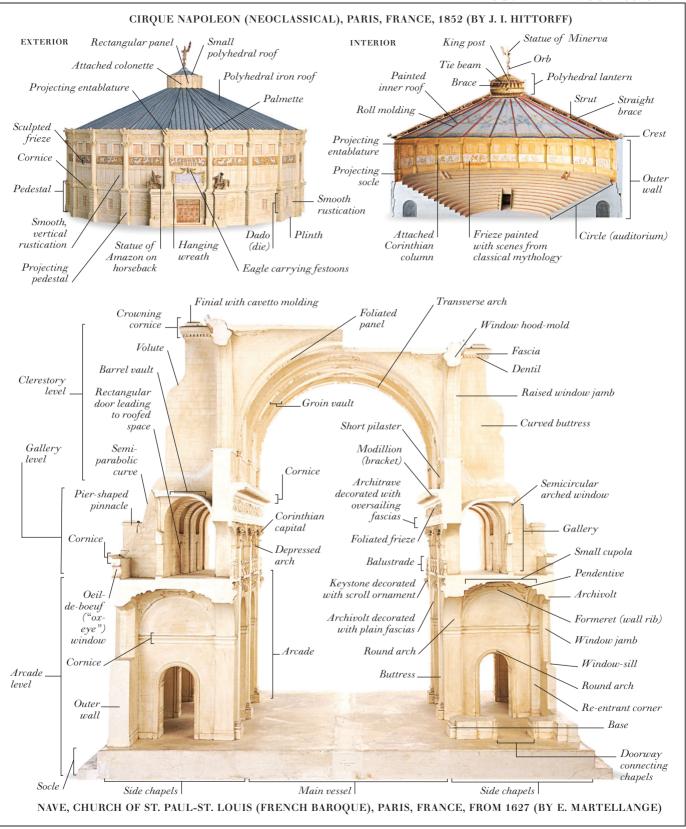
Finial

STATUE OF THE ECSTASY OF ST. THERESA, CHURCH OF ST. MARIA

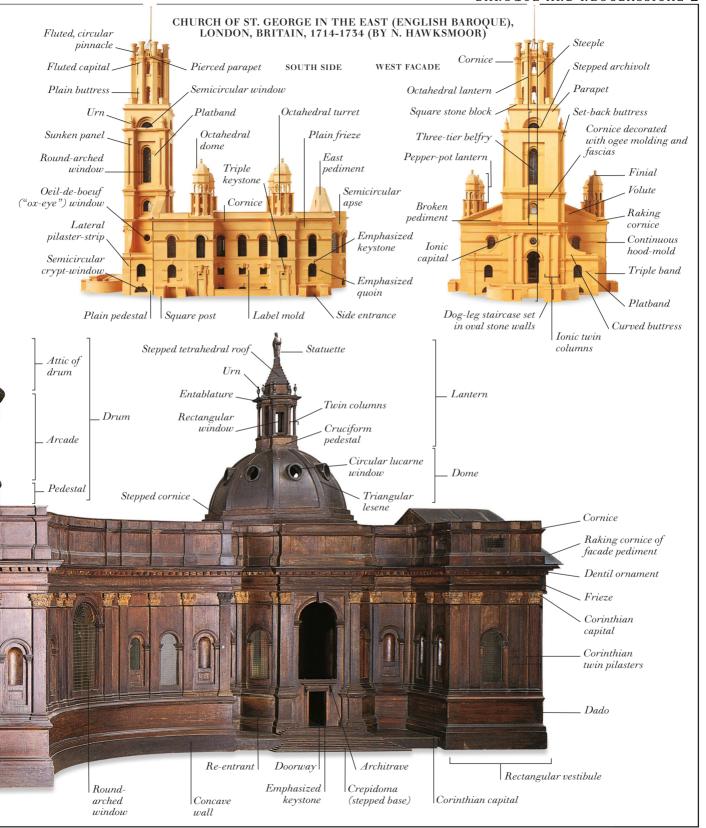


Lantern

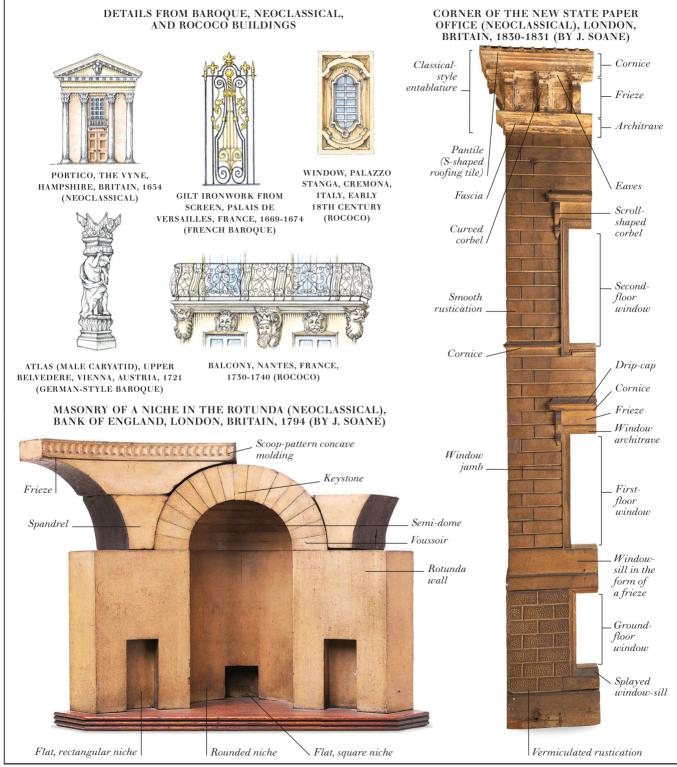
PROPOSED FACADE, THE MADELEINE (NEOCLASSICAL), PARIS, FRANCE, 1764 (BY P. CONTANT D'IVRY)







Baroque and neoclassical 3

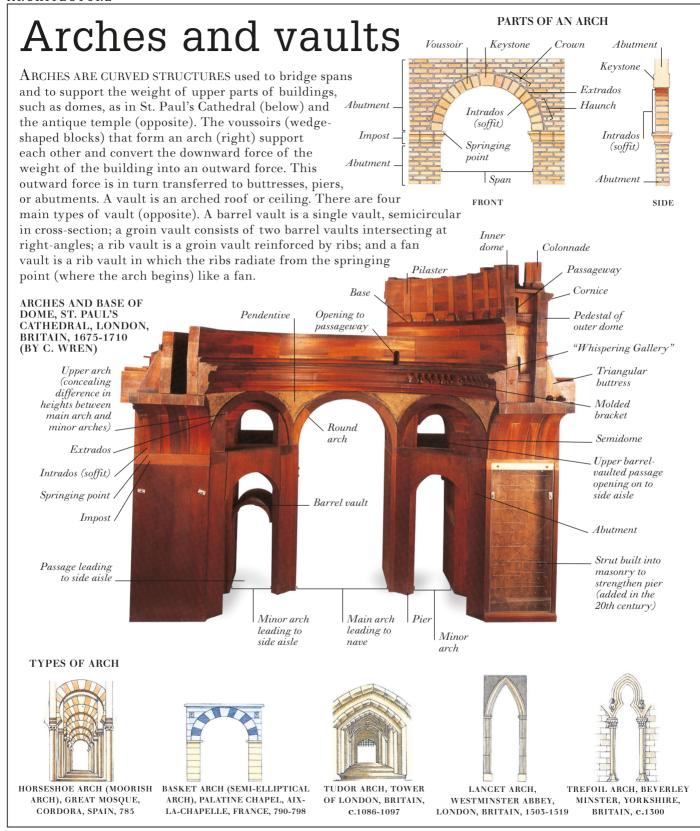


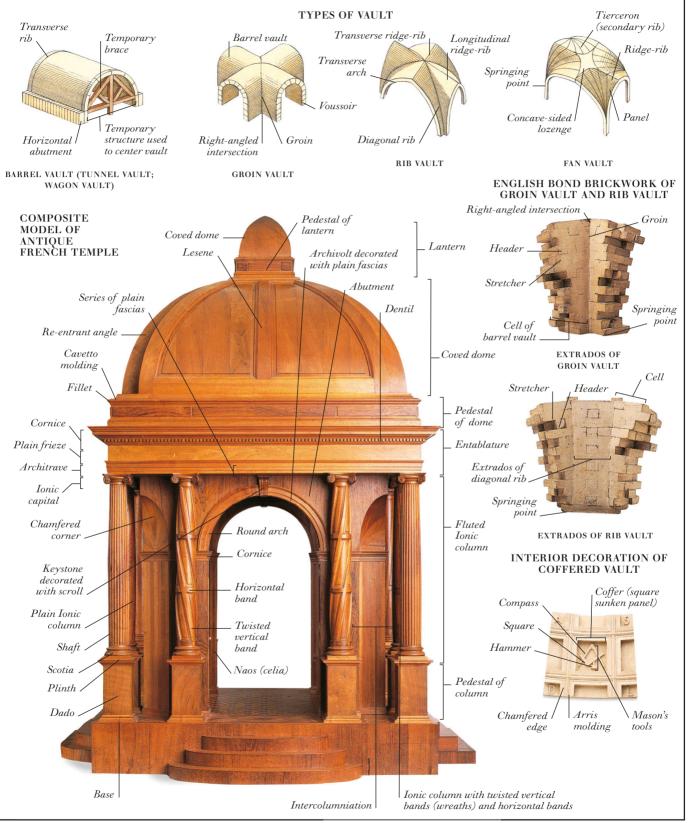
TYRINGHAM HOUSE (NEOCLASSICAL), BUCKINGHAMSHIRE, BRITAIN, 1793-1797 (BY J. SOANE) ROOF LEVEL Space for illumination above unroofed central hall (ATTIC LEVEL) Chimney stack Space above unroofed main staircase Oculus illuminating Flat roof secondary staircase _ Balustrade Parapet rail Baluster Attic story of convex portico Cornice Cornice FIRST-FLOOR LEVEL (CHAMRER FLOOR) Upper level of Main staircase central hall, open to floor below Secondary staircase Abacus Triangular Pilaster capital pilaster. Attached Tuscan First-floor story of twin pilasters convex portico Windowsill GROUND-FLOOR LEVEL Bow front Withdrawing room Central hall (PRINCIPAL FLOOR) Main staircase Library and breakfast room Water closet (toilet) Eating room Secondary staircase Segmented lintel course Band incised with Greek-style fret Windowsill ornament Window jamb Window architrave Base Basement Plinth Ground-floor story of Horizontal rustication convex portico Vestibule Baluster (entrance hall) RailFACADE OF Chimney Balustrade TYRINGHAM HOUSE stack Parapet EntablatureCornice. CapitalIonic column Voussoir. Shaft Basement window BaseCircular

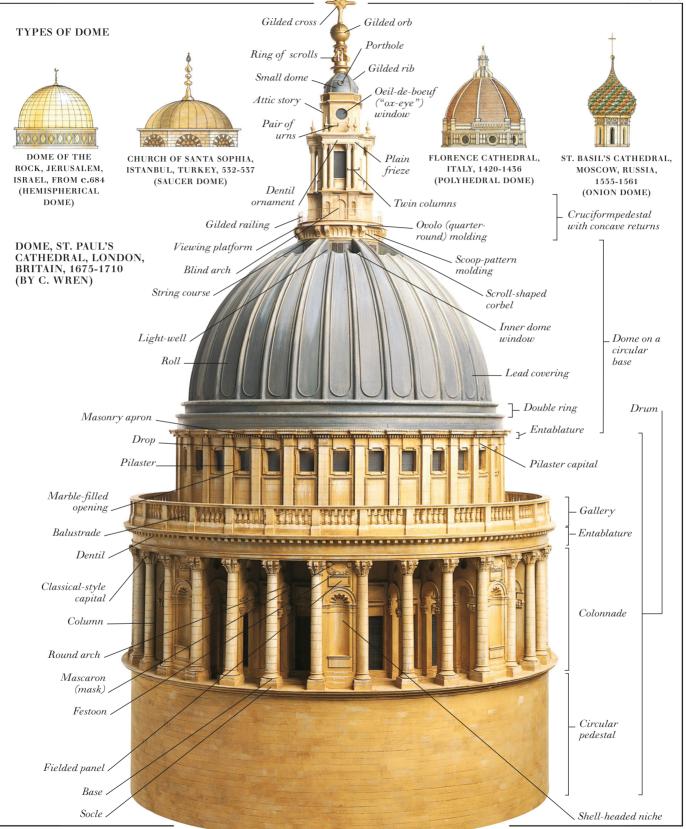
entrance steps

Entrance door

PROSTYLE COLONNADE







Islamic buildings

OPUS SECTILE MOSAIC DESIGN THE ISLAMIC RELIGION was founded by the prophet Muhammad, who was born in Mecca (in present-day Saudi Arabia) about 570 AD. In the following three centuries, Islam spread from Arabia to North Africa and Spain, as well as to India and much of the rest of Asia. The worldwide

ARCH, THE ALHAMBRA, GRANADA, SPAIN, 1333-1354

influence of Islam remains strong today.

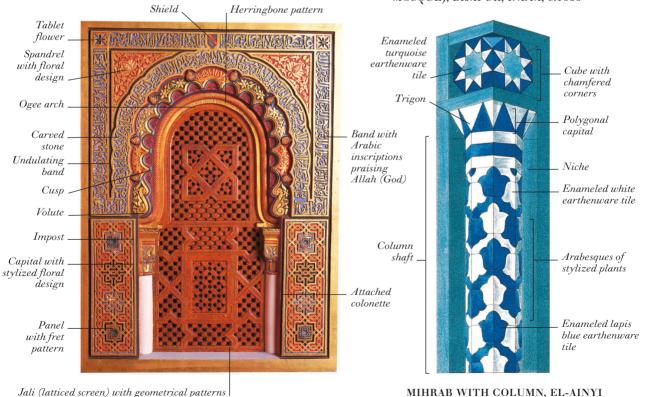
Common characteristics of Islamic buildings include ogee arches and roofs, onion domes, and walls decorated with carved stone, paintings, inlays, or mosaics. The most important type of Islamic building is the mosque—the place of worship—which generally has a minaret (tower) from which the muezzin (official crier) calls

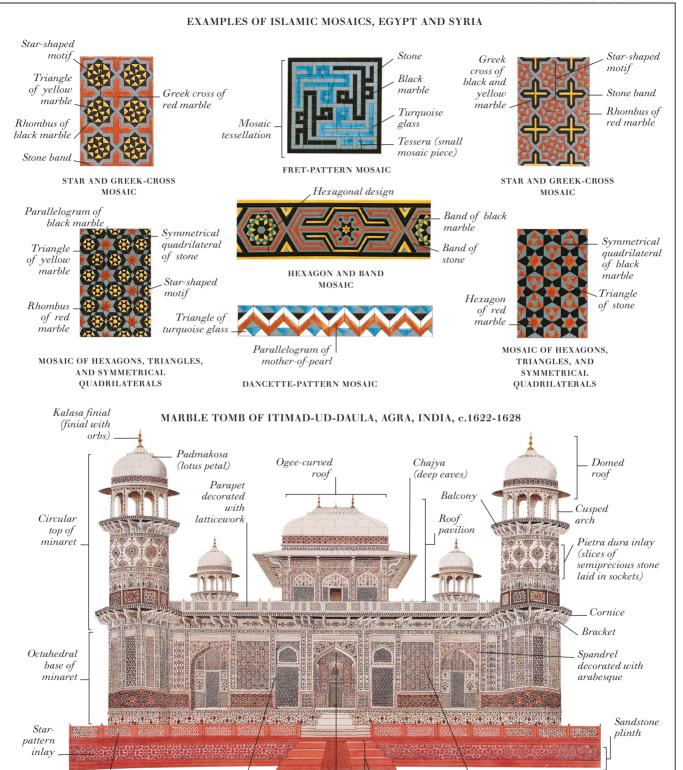
Muslims to prayer. Most mosques have a mihrab (decorative niche) that indicates the direction of Mecca. As figurative art is not allowed in Islam, buildings are ornamented with geometric and arabesque motifs, and inscriptions (frequently Koranic verses).

Budlike Depressed arch surrounding mihrab onion dome Painted roof pavilion Lotus-flower Turkishpendentive crescent finial Arabic Crest inscription minaret with censer (incense burner) Spandrel Series of recessed arches Semidome Arched niche within a niche Mural resembling tomb Polyhedral niche Recessed colonettes

MIHRAB, JAMI MASJID (PRINCIPAL OR CONGREGATIONAL MOSQUE), BIJAPUR, INDIA, c.1636

MOSQUE, CAIRO, EGYPT, 15TH CENTURY





Depressed

entrance arch

Sandstone

stairway

Sandstone parapet

decorated with

latticework

Jali (latticed screen)

with geometrical

patterns

Opus sectile mosaic (geometric

mosaic) of stone, tile, glass,

and enamel

South and east Asia

SEVEN-STORIED PAGODA IN BURMESE STYLE, c.9TH-10TH CENTURY

Gilded

band.

_ Gilded iron hti (crown)

THE TRADITIONAL ARCHITECTURE of south and east Asia has been profoundly influenced by the spread from India of Buddhism and Hinduism. This influence is shown both by the abundance and by the architectural styles of temples and shrines in the region. Many early Hindu temples consist of rooms carved from solid rock-faces. However, free-standing structures began to be built in southern India from about the eighth century AD. Many were built in the Dravidian style, like the Temple of Virupaksha (opposite) with its characteristic antarala (terraced tower), perforated windows, and numerous arches, pilasters, and carvings. The earliest Buddhist religious monuments were Indian stupas, which consisted of a single hemispherical dome surmounted by a chattravali (shaft) and surrounded by railings with ornate gates. Arrow Later Indian stupas and those built elsewhere were sometimes motif modified; for example, in Sri Lanka, the dome became bell-shaped, and was called a dagoba. Buddhist pagodas, such as the Burmese example (right), are multistoried temples, each story having a projecting roof. The form of these buildings probably derived from the yasti (pointed spire) of the stupa. Another feature of many traditional Asian buildings is their imaginative roof-forms, such as gambrel (mansard) roofs, and roofs with angle-rafters (below).

_ Dubika (mast)

— Torus molding with spiral carving

Decorative eaves board

Straight

brace

DETAILS FROM EAST ASIAN BUILDINGS



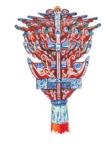
KASUGA-STYLE ROOF WITH SUMIGI (ANGLE-RAFTERS), KASUGADO SHRINE OF ENJOJI, NARA, JAPAN, 12TH-14TH CENTURY



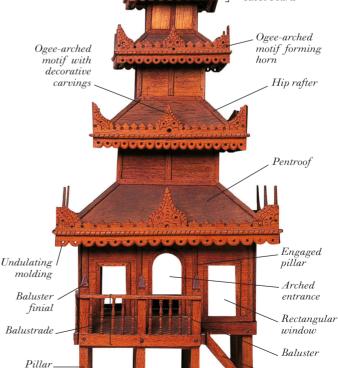
GAMBREL (MANSARD) ROOF WITH UPSWEPT EAVES AND UNDULATING GABLES, HIMEJI CASTLE, HIMEJI, JAPAN, 1608-1609



TERRACES, TEMPLE OF HEAVEN, BEIJING, CHINA, 15TH CENTURY



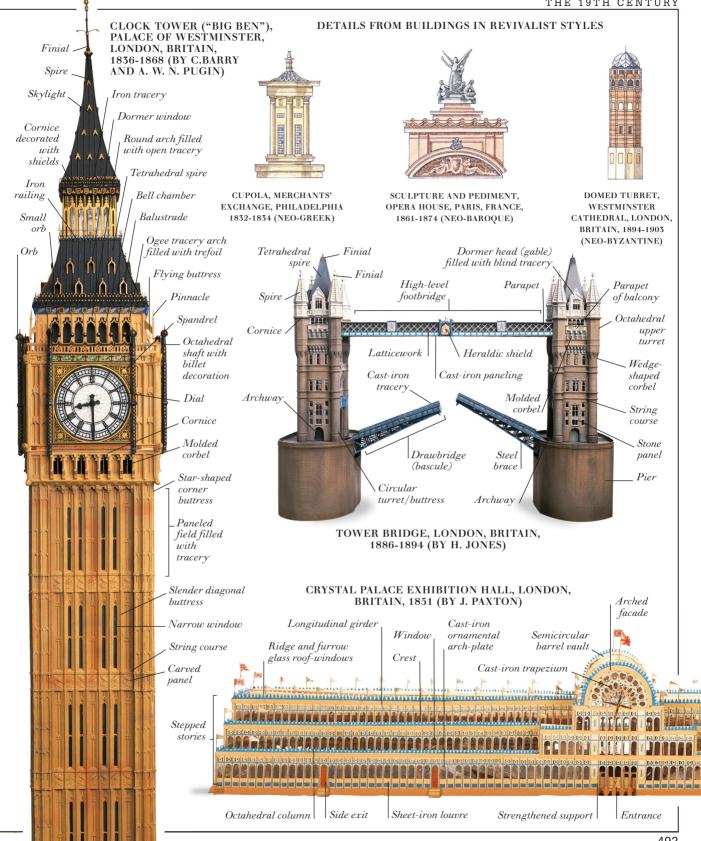
CORNER CAPITAL WITH ROOF BEAMS, POPCHU-SA TEMPLE, POPCHU-SA, SOUTH KOREA, 17TH CENTURY



The 19th century

SECTION THROUGH A FLAX-SPINNING MILL

Cast-iron Pitched Ridge BUILDINGS OF THE 19TH CENTURY are characterized by wall plate roof Machinery Verge the use of new materials and by a great diversity of architectural styles. From the end of the 18th century. Gutter iron and steel became widely used as alternatives to Cast-iron mortise-andwood for the framework of buildings, as in the flaxtenon joint. spinning mill shown here. Built in Britain in 1796. Anchor joint this mill exemplifies an architectural style that became Inverted T-section common throughout the industrialized world for more cast-iron Drainpipe than a century. The Industrial Revolution also brought beam mass-production of building parts—a development Segmentally End flange that enabled the British architect Sir Joseph Paxton arched brick to erect London's Crystal Palace (a building made vault Concrete floor entirely of iron and glass) in only nine months, ready Tapering for the Great Exhibition of 1851. The 19th century part of saw a widespread revival of older architectural column styles. For example, in the US and Germany, Paved. Neo-Greek architecture was fashionable: ground floor in Britain and France, Neo-Baroque, Neo-Byzantine, and Neo-Gothic styles (as seen in the Palace of Multigabled Furrow Strengthened roof (ridge and central Westminster and Tower furrow roof) Timbercolumn Bridge) were dominant. rafter Cast-iron wall-plate FLAX-SPINNING MILL. Gutter SHREWSBURY, BRITAIN, 1796 (BY C. BAGE) GableDrainpipe Tapering part Three courses of column of stretchers Segmentally arched Course of headers brick vault Course of Cast-iron mortisedecorative and-tenon joint headers Cast-iron Tie-rod lattice window Cast-iron cruciform column Cast-iron tenon Inverted T-section Anchor-joint cast-iron beam Strengthened central Bonded column brick wall Gauged arch (segmental arch of tapered bricks) JambStone foundation Quoin

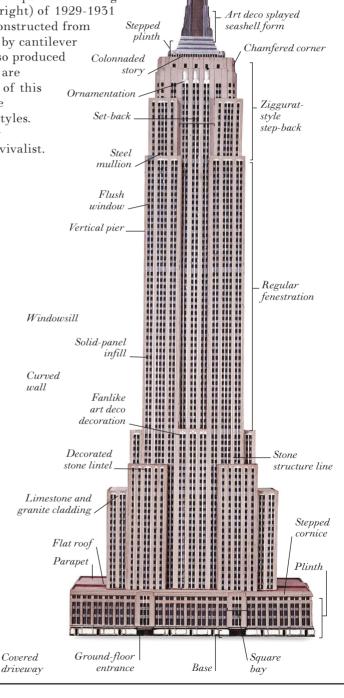


The early 20th century

ARCHITECTURE OF THE EARLY 20TH CENTURY is notable for radical new types of steel-and-glass buildings—particularly skyscrapers—and the widespread use of steel-reinforced concrete. The steel-framed skyscraper was pioneered in Chicago in the 1880s, but did not become widespread until the first decades of the 20th century. As construction techniques were refined, skyscrapers became higher and higher; for example, the Empire State Building (right) of 1929-1931 has 102 stories. Many buildings of this period were constructed from lightweight concrete slabs, which could be supported by cantilever beams or by pilotis (stilts). The early 20th century also produced a great variety of architectural styles, some of which are illustrated opposite. Despite their diversity, the styles of this period generally had one thing in common: they were completely new, with few links to past architectural styles.

This originality is in marked contrast to 19th century architecture (see pp. 492-493), much of which was revivalist.

The Empire State Building's top 30 floors were first illuminated in color in 1976 to honor the United States Bicentennial. This marked the beginning of the Lighting Partners Program that today sees the building lit up in specific colors for many occasions. Above, the blue, white, and red lights celebrate Independence Day.



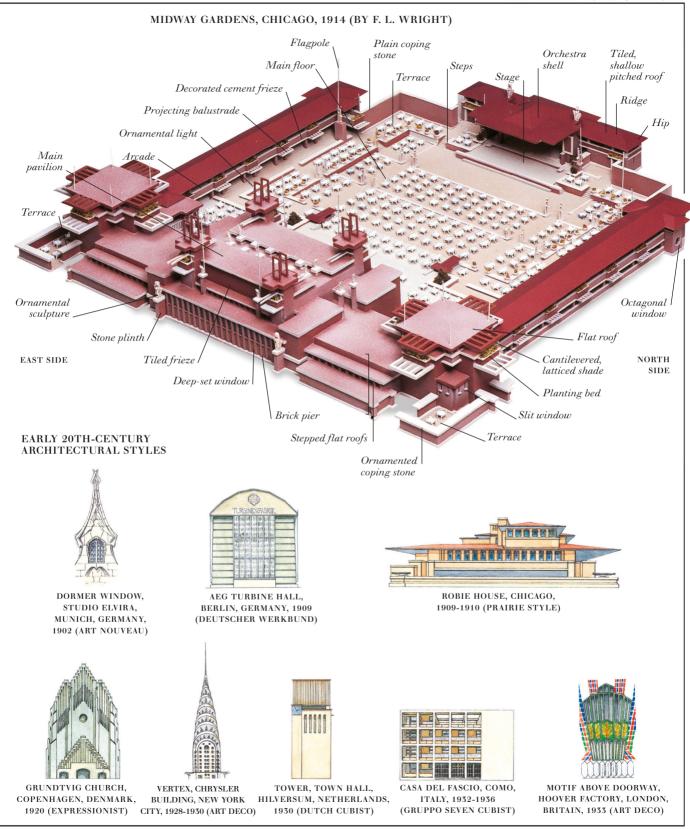
EMPIRE STATE

A. L. HARMON)

Radio mast

Circular lantern

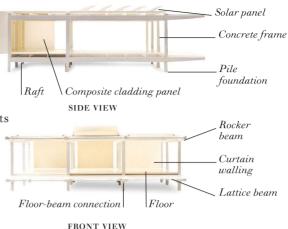
BUILDING, NEW YORK, USA, 1929-1931 (BY R. H. SHREVE, T. LAMB, AND



Modern buildings 1

KAWANA HOUSE, JAPAN, FROM 1987 (BY N. FOSTER)

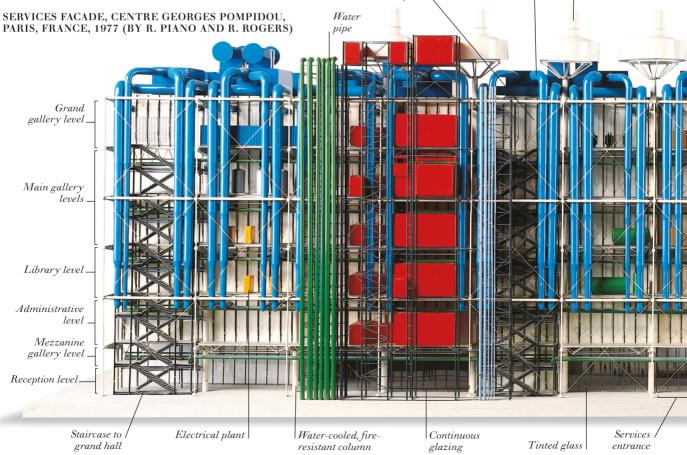
ARCHITECTURE SINCE ABOUT THE 1950s is generally known as modern architecture. One of its main influences has been functionalism—a belief that a building's function should be apparent in its design. Both the Centre Georges Pompidou (below and opposite) and the Hong Kong and Shanghai Bank (see pp. 498-499) are functionalist buildings: on each, elements of engineering and the building's services are clearly visible on the outside. In the 1980s, some architects rejected functionalism in favor of post-modernism, in which historical styles—particularly neoclassicism—were revived, using modern building materials and techniques. In many modern buildings, walls are made of glass or concrete hung from a frame, as in the Kawana House (right); this type of wall construction is known as curtain walling. Other modern construction techniques include the intricate interlocking of concrete vaults—as in the Sydney Opera House (see pp. 498-499)—and the use of high-tension beams to create complex roof shapes, such as the paraboloid roof of Metal-faced, fire-resistant the Church of St. Pierre de Libreville (see pp. 498-499).



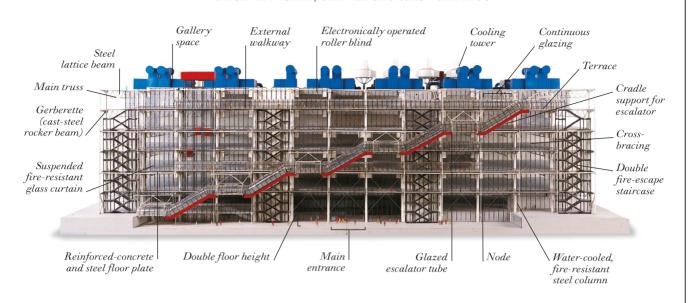
Air-conditioning

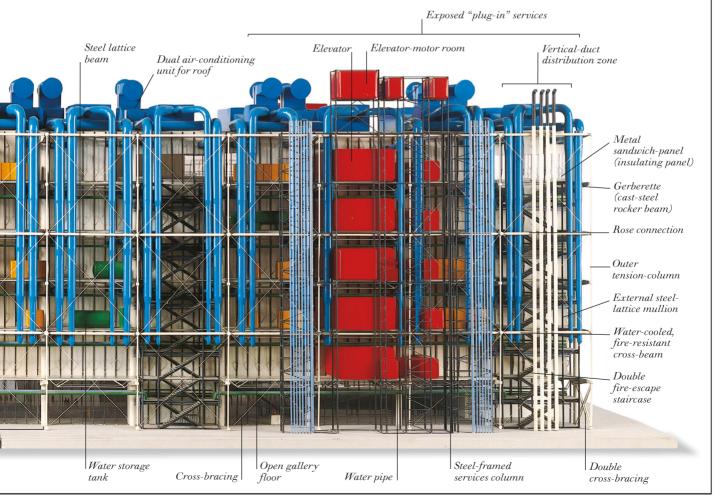
nanel.

Cooling tower



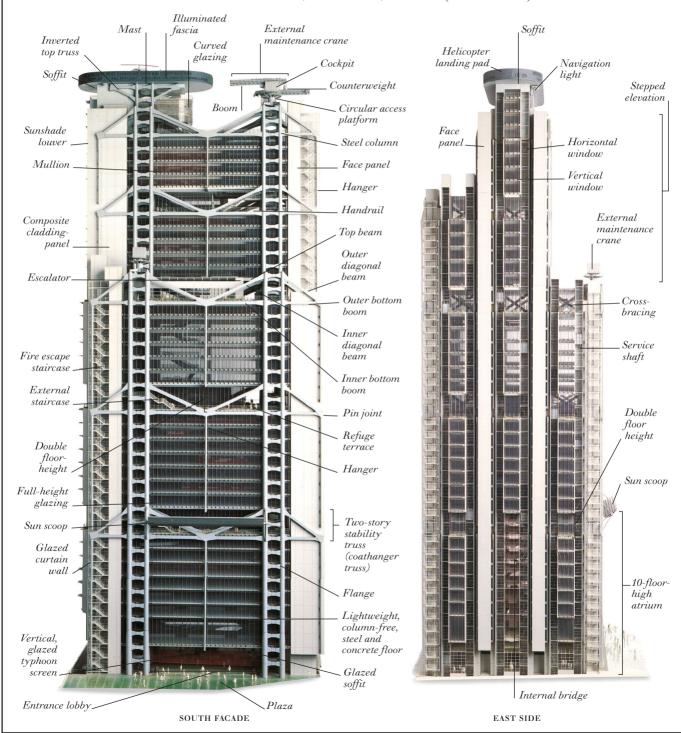
PRINCIPAL FACADE, CENTRE GEORGES POMPIDOU

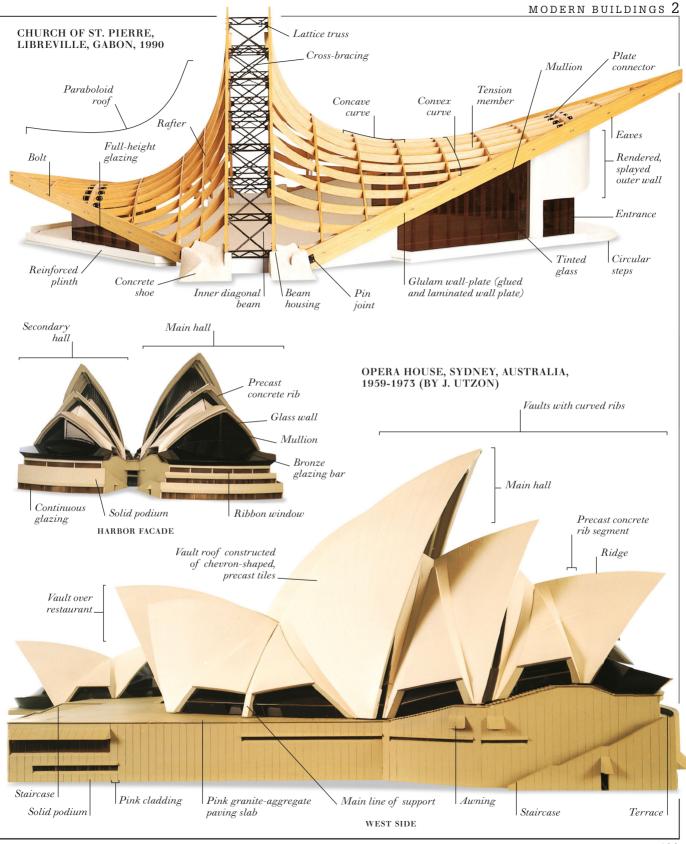




Modern buildings 2

HONG KONG AND SHANGHAI BANK, HONG KONG, 1981-1985 (BY N. FOSTER)









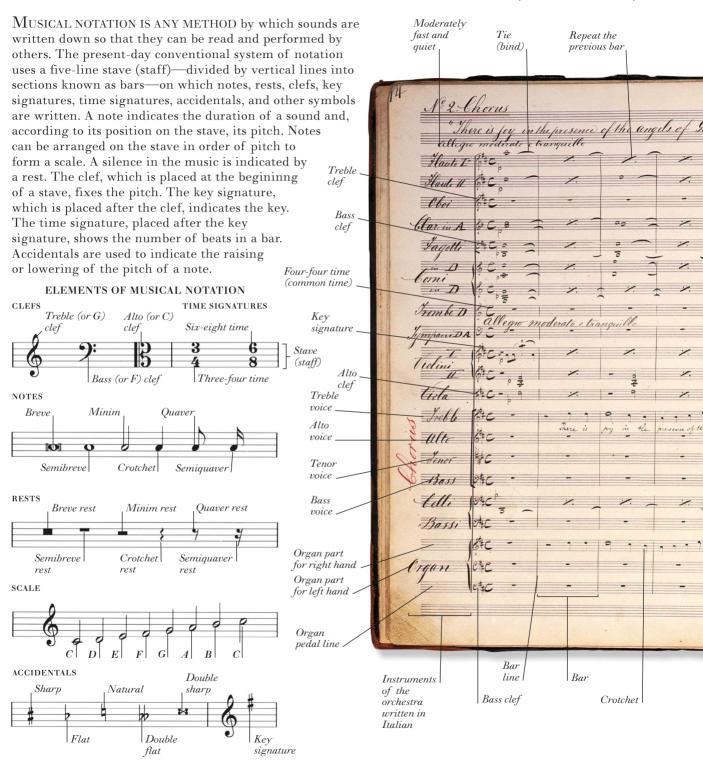
Music

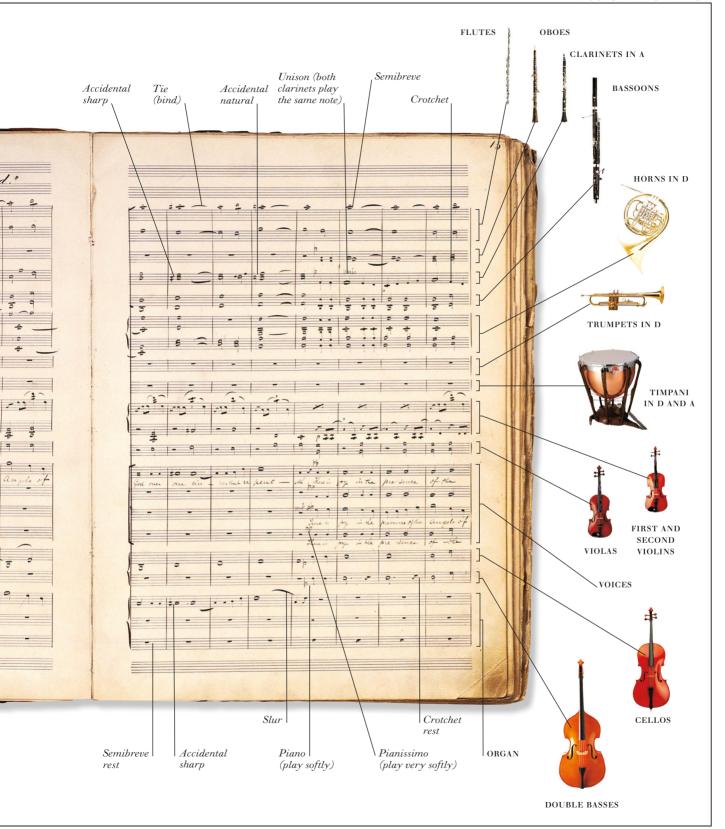
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Keyboard Instruments 514
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Drums518
ELECTRONIC INSTRUMENTS 520



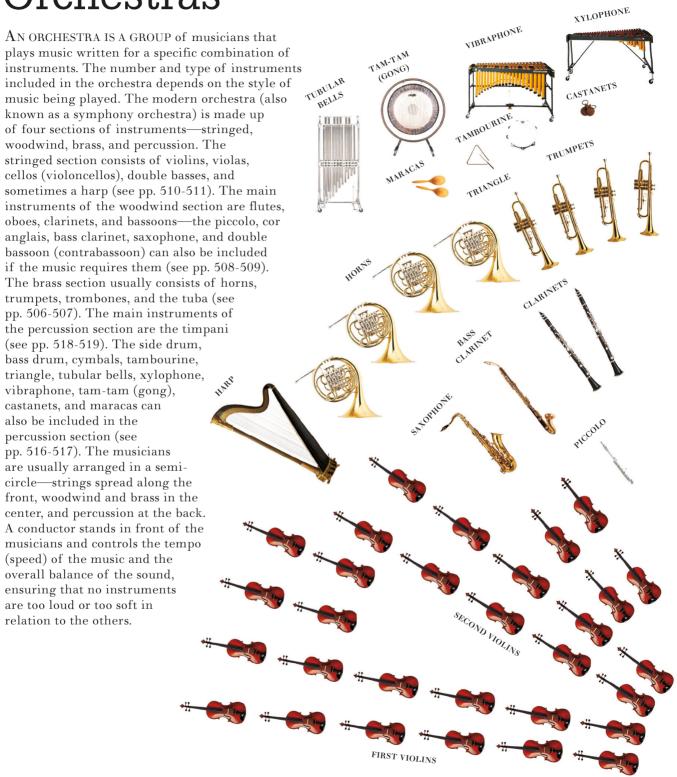
Musical notation

EXAMPLE OF AN ORIGINAL MANUSCRIPT: THE PRODIGAL SON, ARTHUR SULLIVAN, 1869





Orchestras





Brass instruments

conical, as in the horn and tuba, or mainly cylindrical, as in the trumpet and trombone. The sound of a brass instrument

is made by the player's lips vibrating against the mouthpiece, so that the air vibrates in the tube. By changing lip tension,

the player can vary the vibrations and produce notes of different pitches. The range of notes produced by a brass instrument can be extended by means of a valve system. Most brass instruments, such as the trumpet, have piston valves that divert the air in the instrument along an extra piece of tubing (known as a valve slide) when pressed down. The total length of the tube is increased and the pitch of the

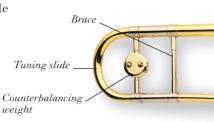
note produced is lowered. Instead of valves, the trombone

has a movable slide that can be pushed away from or drawn

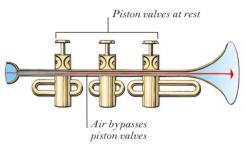
toward the player. The sound of a brass instrument can also

Brass instruments are wind instruments that are made of metal, usually brass. Although they appear in many different shapes and sizes, all brass instruments have a mouthpiece, a length of hollow tube, and a flared bell. The mouthpiece of a brass instrument may be cupshaped, as in the cornet, or cone-shaped, as in the

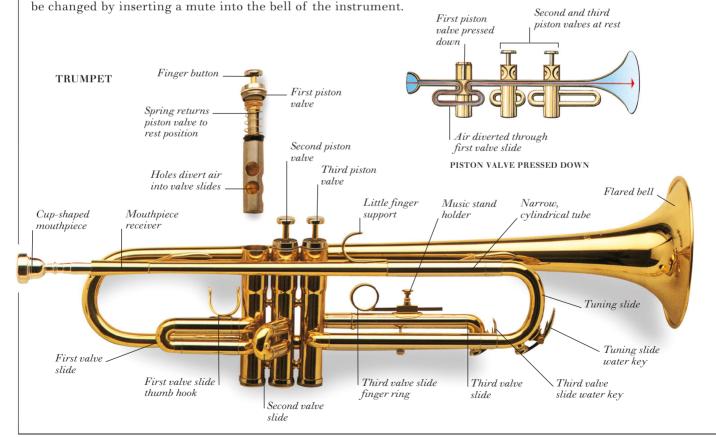
horn. The tube may be wide or narrow, mainly

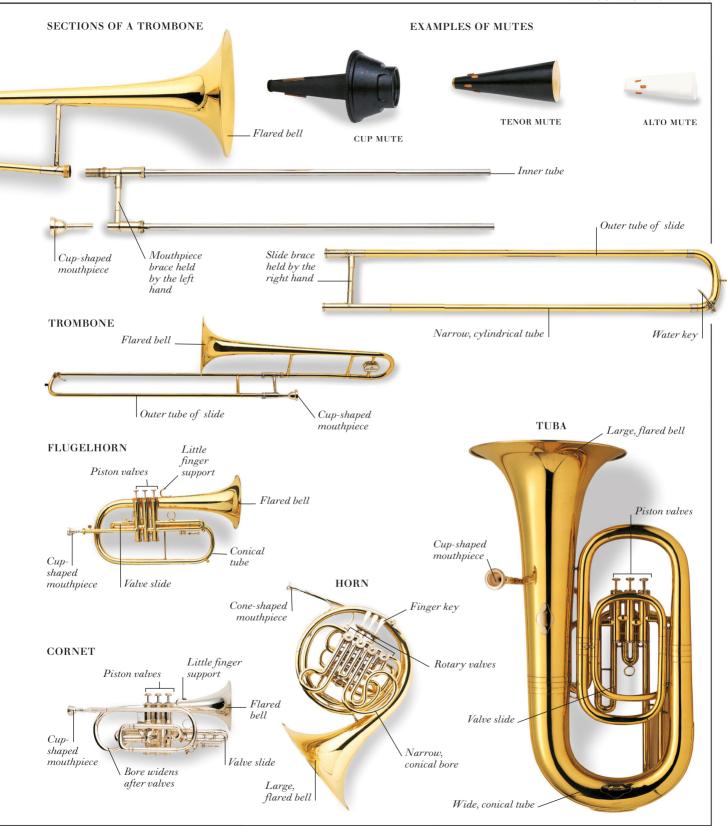


SIMPLIFIED DIAGRAM SHOWING HOW A PISTON VALVE SYSTEM WORKS



PISTON VALVES AT REST





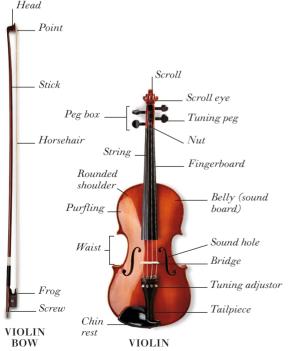


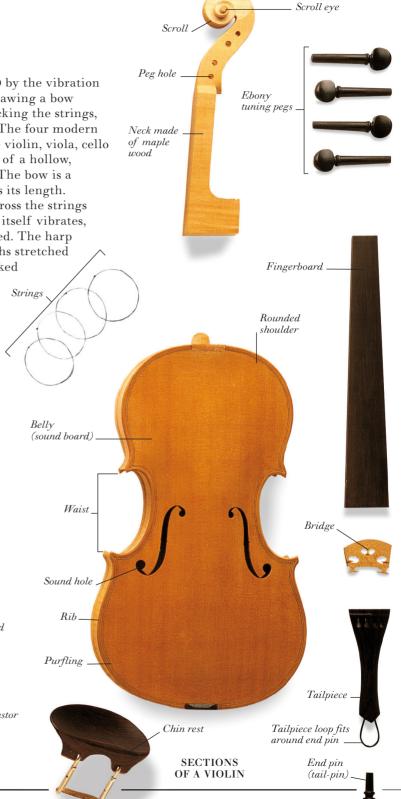


Stringed instruments

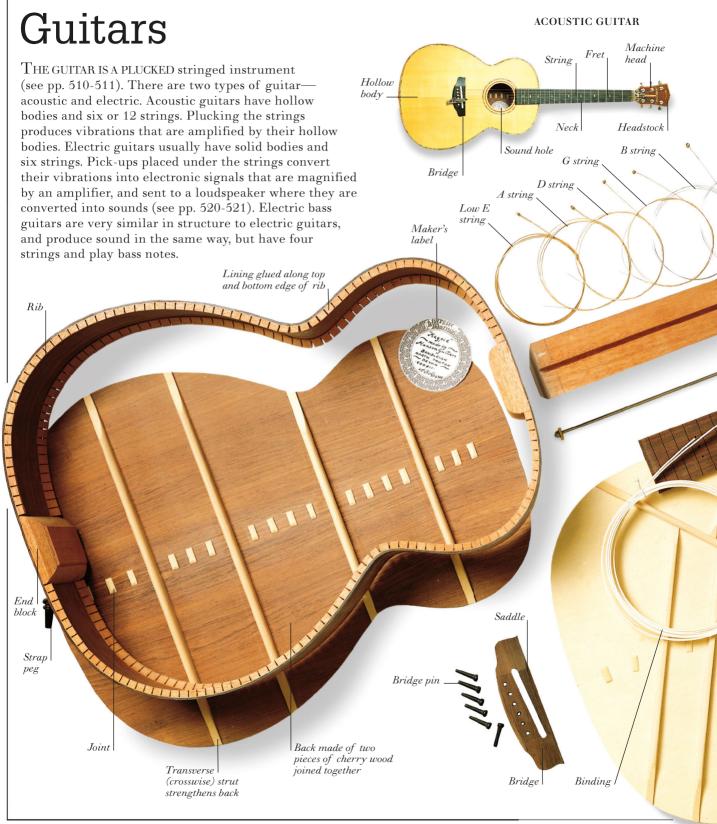
STRINGED INSTRUMENTS PRODUCE SOUND by the vibration of stretched strings. This may be done by drawing a bow across the strings, as in the violin; or by plucking the strings, as in the harp and guitar (see pp. 512-513). The four modern members of the bowed string family are the violin, viola, cello (violoncello), and double bass. Each consists of a hollow, wooden body, a long neck, and four strings. The bow is a wooden stick with horsehair stretched across its length. The vibrations made by drawing the bow across the strings are transmitted to the hollow body, and this itself vibrates, amplifying and enriching the sound produced. The harp consists of a set of strings of different lengths stretched across a wooden frame. The strings are plucked by the player's thumbs and fingers—except Strings the little finger of each hand—which produces vibrations that are amplified

the little finger of each hand—which produces vibrations that are amplified by the harp's sound board. The pitch of the note produced by any stringed instrument depends on the length, weight, and tension of the string. A shorter, lighter, or tighter string gives a higher note.











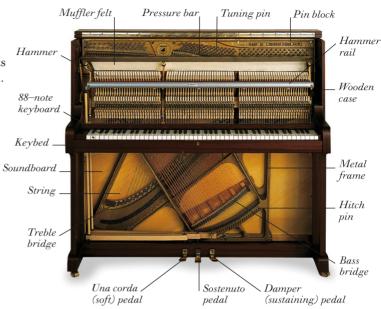
ORGAN

Keyboard instruments

KEYBOARD INSTRUMENTS are instruments that are sounded by means of a keyboard. The organ and piano are two of the principal members of the keyboard family. The organ consists of pipes that are operated by one or more manuals (keyboards) and a pedal board. The pipes are lined up in rows (known as ranks or registers) on top of a wind chest. The sound of the organ is made when air is admitted into a pipe by pressing a key or pedal. The piano consists of wire strings stretched over

PIPE consists of wire strings stretched over a metal frame, and a keyboard and pedals that operate hammers and dampers. The piano frame is either vertical—as in the upright piano—or horizontal—as in the grand piano. When a key is at rest, a damper lies against the string to stop it from vibrating. When a key is pressed down, the damper moves away from the string as the hammer strikes it, causing the string to vibrate and sound a note.

UPRIGHT PIANO



UPRIGHT PIANO ACTION

KEY AT REST





Percussion instruments



PERCUSSION INSTRUMENTS are a large group of instruments that produce sound by being struck, shaken, scraped, or clashed together. Most percussion instruments—such as the tam-tam (gong), cymbals, and maracas—do not have a definite pitch and are used for rhythm and impact, and the distinctive

TUBULAR BELLS

Tube struck

with mallet

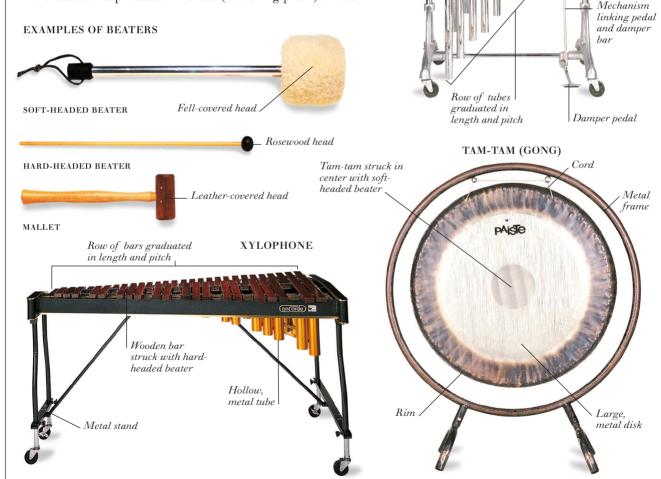
Hollow, metal tube

Metal

frame

TEMPLE BLOCKS

timber (color) of their sound. Other percussion instruments—such as the xylophone, vibraphone, and tubular bells—are tuned to a definite pitch and can play melody, harmony, and rhythms. The xylophone and vibraphone each have two rows of bars that are arranged in a similar way to the black and white keys of a piano. Metal tubes are suspended below the bars to amplify the sound. The vibraphone has electrically operated fans that rotate in the tubes and produce a vibrato (wavering pitch) effect.









Electronic instruments

ELECTRONIC INSTRUMENTS generate electronic signals that are magnified by an amplifier and sent to a loudspeaker, where they are converted into sounds. Synthesizers, and other electronic instruments, simulate the characteristic sounds of conventional instruments, and also create entirely new sounds. Most electronic instruments are keyboard instruments, but electronic wind and percussion instruments are also popular. A digital sampler records and stores sounds from musical instruments or other sources. When the sound is played back, the pitch of the original sound can be altered. A keyboard can be connected to the sampler so that a tune can be played using the sampled sounds. With a MIDI (Musical Instrument Digital Interface) system, a computer can be linked with other electronic instruments, such as keyboards and electronic drums, to make sounds together or in sequence. It is also possible, using music software, to compose and play music on a home computer.

HOME KEYBOARD Power Volume Function Memory record display button Tone editor button control controlDemonstration tune button Key Pitch Multiaccompaniment Tone and rhythm Tripodmodulator system control pattern selector SYNTHESIZER

ELECTRONIC DRUMS

Drum pad

Height adjustment key





COMPUTER WITH MIDI AND AUDIO SOFTWARE SEQUENCER





SPORTS

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Soccer

GAMES INVOLVING KICKING A BALL have a long history and were recorded in China as early as 300 BC; in medieval Europe, street football was banned as a menace to the public; only in 1863 were the rules established, specifically banning carrying the ball for all players except the goalkeeper, and separating rugby from soccer. Soccer, officially termed association football, is a team sport in which players attempt to score goals by passing and dribbling the ball down the field past opposing defenders, and kicking or heading the ball into the goal net, outwitting the defending goalkeeper. Each team consists of 10 outfield players (defenders, midfielders, and strikers) and a goalkeeper. Players from the opposing team may challenge the player in possession of the ball, but an illegal or foul tackle results in a penalty if a foul occurs inside the penalty area or a free kick if outside the penalty area. The round ball used in soccer is more easily controlled than the oval balls used in American, Canadian, and Australian rules football and in rugby. The result is a more "open" or flowing game that is played and watched by millions of people worldwide.

130-300 ft

(46-91 m)

Goal

Goal line

Assistant

referee

Center

Halfway line

Striker

Right

Right back

Central

defender

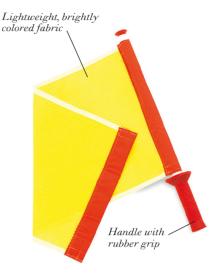
Goal

Goalkeeper

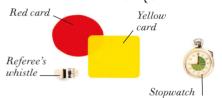
midfielder

circle Center spot

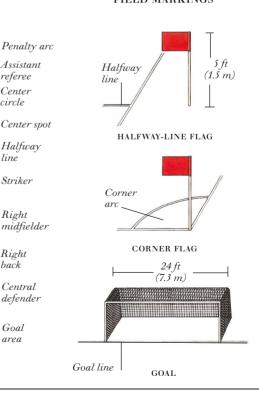
ASSISTANT REFEREE'S FLAG



REFEREE'S EQUIPMENT



FIELD MARKINGS





Corner flag

Corner arc Penalty. area

Penalty

Referee

Halfway-

line flag

Striker

Striker

midfielder

Central. midfielder.

Left back

Touch

defender

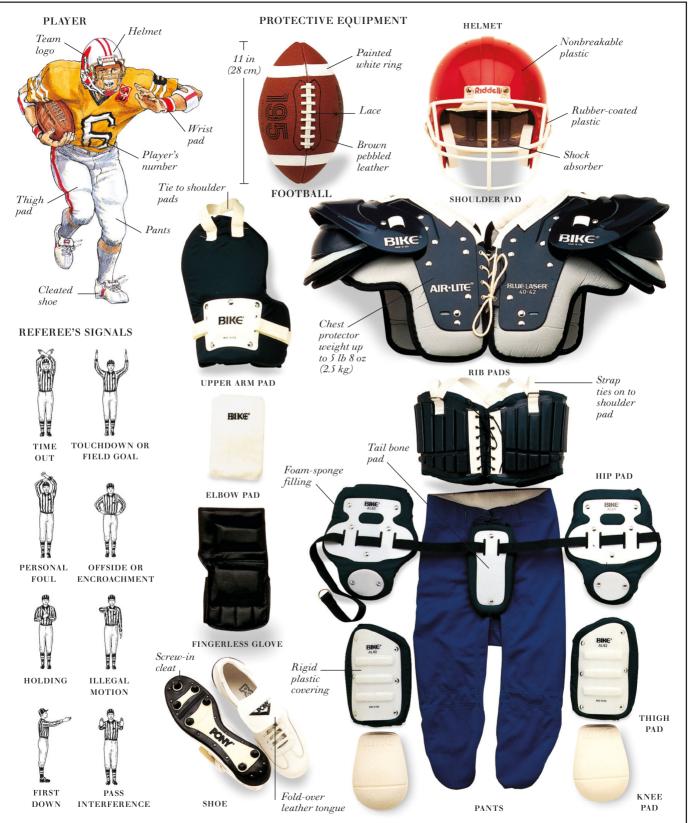
line Central

Left

mark



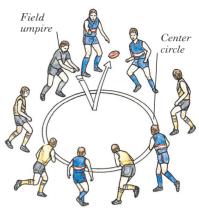
FOOTBALL FIELD Football Goalpost End line Inbound IN AMERICAN AND CANADIAN FOOTBALL, the object of the game Goalline is to get the ball across the opponent's goal line, either by passing or carrying it across (a touchdown), or by kicking it between their Sideline goalposts (a field goal). An American football team has 11 players on the field at a time, although up to 40 players can appear for each side in a single game. The agile "offense" tries to score points, and Players' the heavy hitting "defense" holds back the opposition. When in bench. possession of the ball, a team has four chances ("downs"), to move it at least ten yards (nine meters) up the field to make a "first down." The opposition gains possession if they fail, or by tackling and intercepting the ball. Canadian football is played on a larger field. Referee with 12 men on each side. A team has only three chances to Umpire achieve a first down. Otherwise, the game is very similar to American football. Helmets, face masks, and layers of body padding are worn by the players for protection. Back judge AMERICAN FOOTBALL PLAYING FORMATION 30 ft Right safety Middle linebacker _ Left safety $(9.2\,m)$ Right defensive Left defensive tackle tackle EndInside linebacker Right zone cornerback Left cornerback GOALPOST Outside linebacker 160 ft 6 in Left defensive end Right defensive end Center (49 m)Split end CANADIAN FOOTBALL FIELD Tight end _ Right tackle Left tackle Right guard GoalpostLeft guard Ouarter back Goalline Left half-back Right half-back Fullback CANADIAN FOOTBALL PLAYING FORMATION Right Players Safety Left defensive back defensive Middle bench Left defensive tackle linebacke. back Referee Right Left cornerback Umpire Yardsman cornerback Left outside Field judge linebacker Right outside linebacker Head Left defensive end linesman Right defensive end Right guard Yardsman WideWide receiver receiver 30 ft Right . Sideline (9.2 m)Right tackle defensive tackle Left Flanker guard End Running back Center zone Left tackle Quarter back 195 ft Fullback GOALPOST $(59.5^{\circ}m)$ Halfback



Australian rules and Gaelic football

VARIETIES OF FOOTBALL have developed all over the world and Australian rules football is considered to be one of the roughest versions, allowing full body tackles even though participants wear no protective padding. The game is played on a large, oval field by two sides, each of 18 players. Players can kick or punch the ball, which is shaped like a rugby ball, but cannot throw it. Running with the ball is permitted, as long as the ball touches the ground at least once every 10 meters. The fullbacks defend two sets of posts. Teams try to score "goals" (six points) between the inner posts or "behinds" (one point) inside the outer posts. Each game has four quarters of 25 minutes, and the team with the most points at the end of the allotted time is the winner. In Gaelic football, an Irish version of soccer (see pp. 524–525), a size 5 soccer ball is used. Each team can have 15 players on the field at a time. Players are allowed to catch, fist, and kick the ball, or dribble it using their hands or feet, but cannot throw it. Teams are awarded three points for getting the ball into the net, and one point for getting it through the posts above the crossbar. Gaelic football is rarely played outside of Ireland.

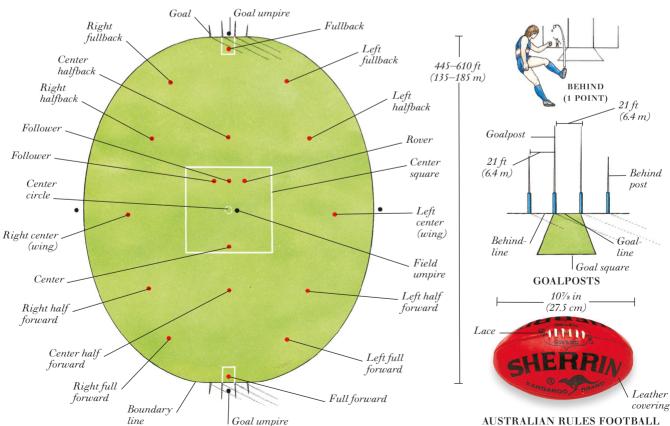
START OF PLAY

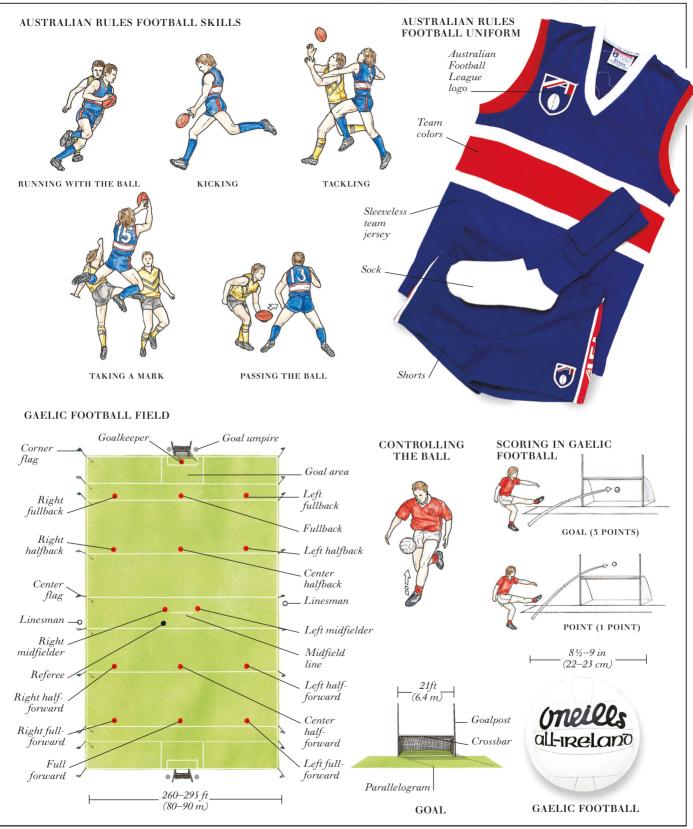


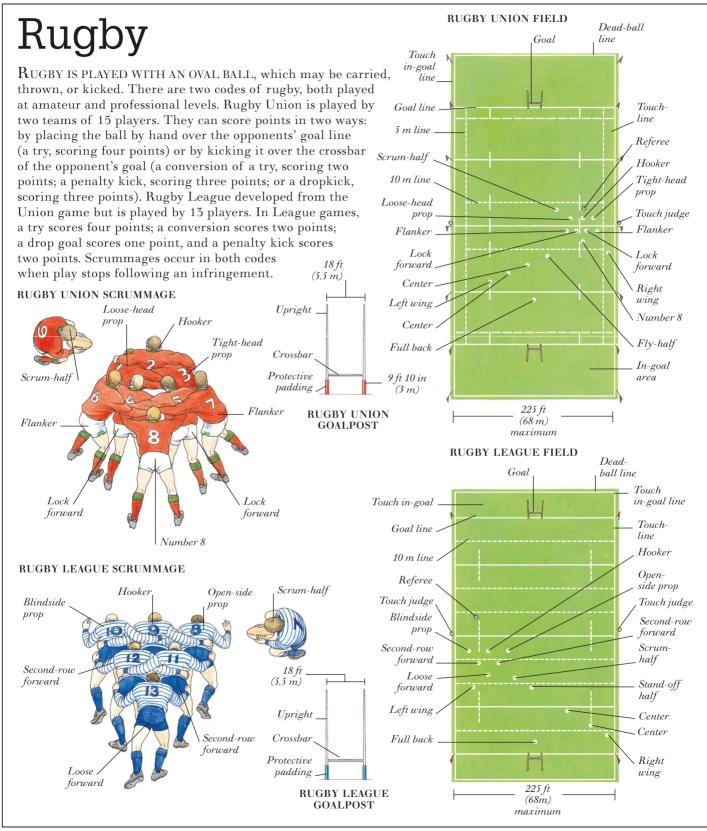
SCORING



AUSTRALIAN RULES FOOTBALL FIELD









Basketball

INTERNATIONAL BASKETBALL COURT

BASKETBALL IS A BALL GAME for two teams of five players, originally devised in 1890 by James Naismath for the Y.M.C.A. in Springfield, Massachusetts. The object of the game is to take possession of the ball and score points by throwing the ball into the opposing team's basket. A player moves the ball up and down the court by bouncing it along the ground or "dribbling"; the ball may be passed between players by throwing, bouncing, or rolling. Players may not run with or kick the ball, although pivoting on one foot is allowed. The game begins with the referee throwing the ball into the air and a player from each team jumping up to try and "tip" the ball to a teammate. The length of the game and the number of periods played varies at different levels. There are amateur, professional, and international rules. No game ends in a draw. An extra period of five minutes is played, plus as many extra periods as are necessary to break the tie. In addition to the five players on court, each team has up to seven substitutes, but players may only leave the court with the permission of the referee. Basketball is a noncontact sport and fouls on other players are penalized by a throw-in awarded against the offending team; a free throw at the basket is awarded when a player is fouled in the act of shooting. Basketball is a fast-moving game, requiring both physical and mental coordination. Skillful tactical play matters more than simple physical strength and the agility of the players makes the game an excellent spectator sport.

BASKETBALL SKILLS



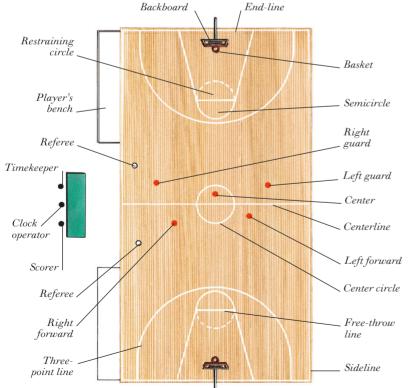
CHEST PASS



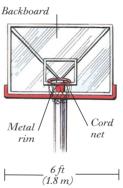
DRIBBLE



OVERHEAD PASS



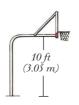
49 ft (15 m) —



BASKET AND BACKBOARD

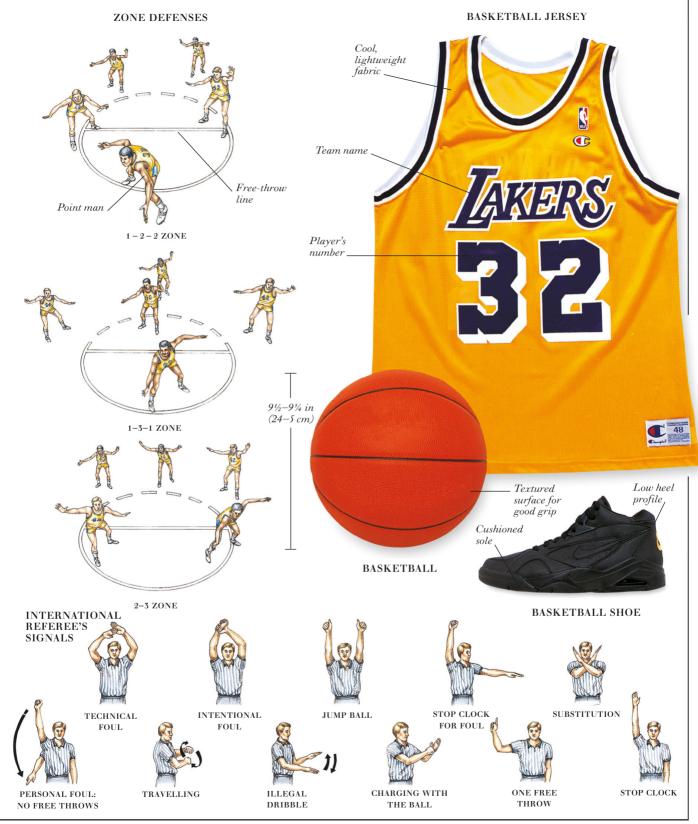


BASKET AND BACKBOARD STRUCTURE



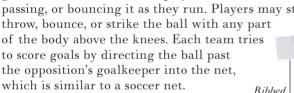


LONG PASS

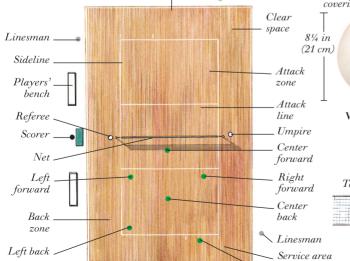


Volleyball, netball, and handball

VOLLEYBALL, NETBALL, AND HANDBALL are fast-moving team sports played with balls on courts with a hard surface. In volleyball, the object of the game is to hit the ball over a net strung across the center of the court so that it touches the ground on the opponent's side. The team of six players can take three hits to direct the ball over the net, although the same player cannot hit the ball twice in a row. Players can hit the ball with their arms, hands, or any other part of their upper body. Teams score points only while serving. The first team to score 15 points, with a two-point margin over their opponent, wins the game. Netball is one of the few sports played exclusively by women. Similar to basketball (see pp. 532–533), it is played on a slightly larger court with seven players instead of five. A team moves the ball toward the goal by throwing, passing, and catching it with the aim of throwing the ball through the opponents' goal net. Players are confined by their playing position to specific areas of the court. Team handball is one of the world's fastest games. Each side has seven players. A team moves the ball by dribbling, passing, or bouncing it as they run. Players may stop, catch,



of the body above the knees. Each team tries to score goals by directing the ball past the opposition's goalkeeper into the net, which is similar to a soccer net. Ribbed cuff VOLLEYBALL COURT Endline Linesman



29 ft 6 in

VOLLEYBALL SHOTS

OVERHAND SERVE

SPIKE (SMASH)







UNDERHAND SERVE

FOREARM PASS (DIG) UNIFORM

Team

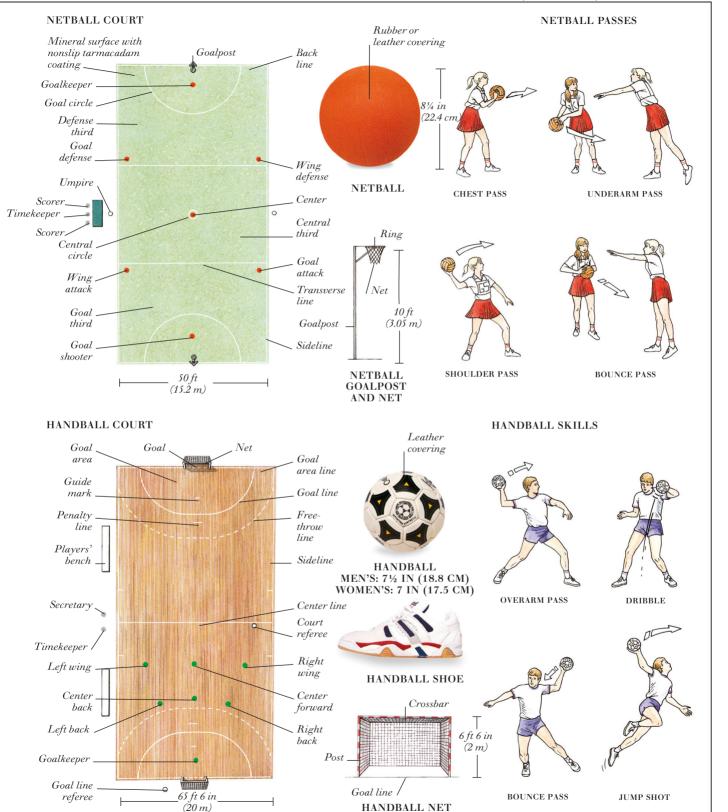
colors



KNEE PADS

VOLLEYBALL NET

Linesman



Baseball

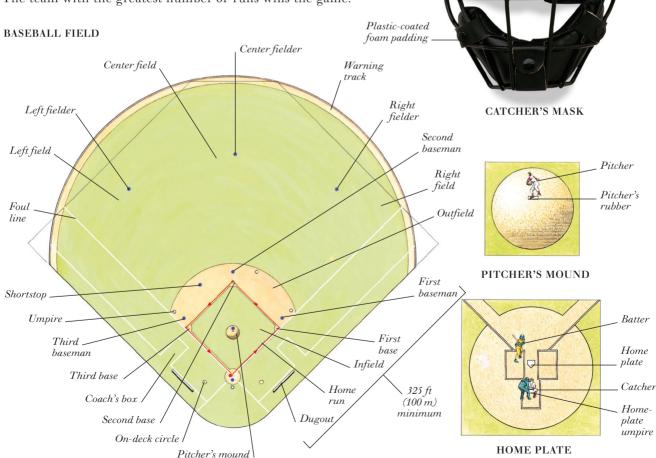
Baseball is a ball game for two teams of nine players. The batter hits the ball thrown by the opposing team's pitcher, into the area between the foul lines. He then runs around all four fixed bases in order to score a run, touching or "tagging" each base in turn. The pitcher must throw the ball at a height between the batter's armpits and knees, a height which is called the "strike zone." A ball pitched in this area that crosses over the "home plate" is called a "strike" and the batter has three strikes in which to try and hit the ball (otherwise he is "struck out"). The fielding team tries to get the batting team out by catching the ball before it bounces, tagging a player of the batting team with the ball who is running between bases, or by tagging a base before the player has reached it. Members of the batting team may stop safely at a base as long as it is not occupied by another member of their team. When the batter runs to first base, his teammate at first base must run on to second—this is called "force play." A game consists of nine innings and each team will bat once during an inning. When three members of the batting team are out, the teams swap roles. The team with the greatest number of runs wins the game.

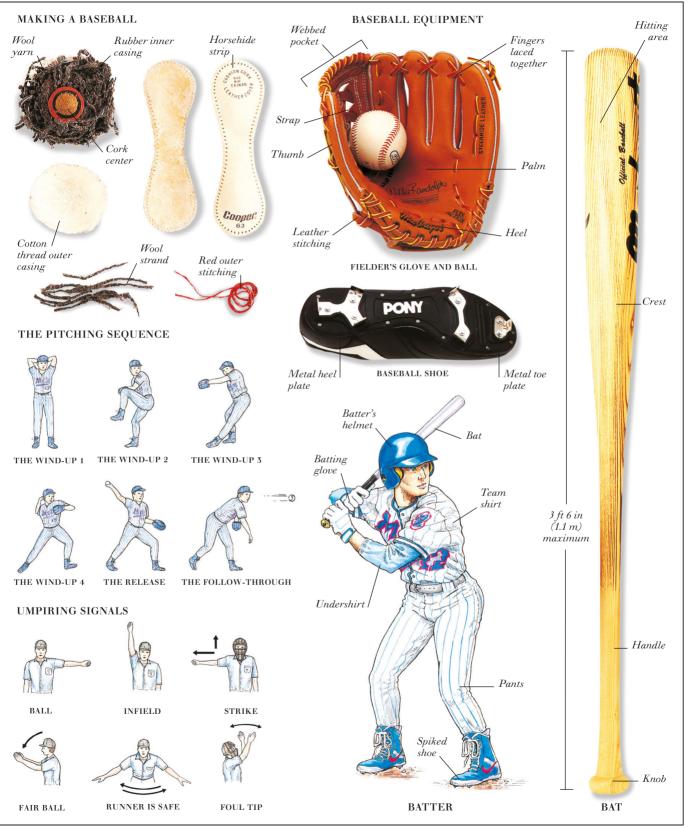


Wire coated

in strong

nylon



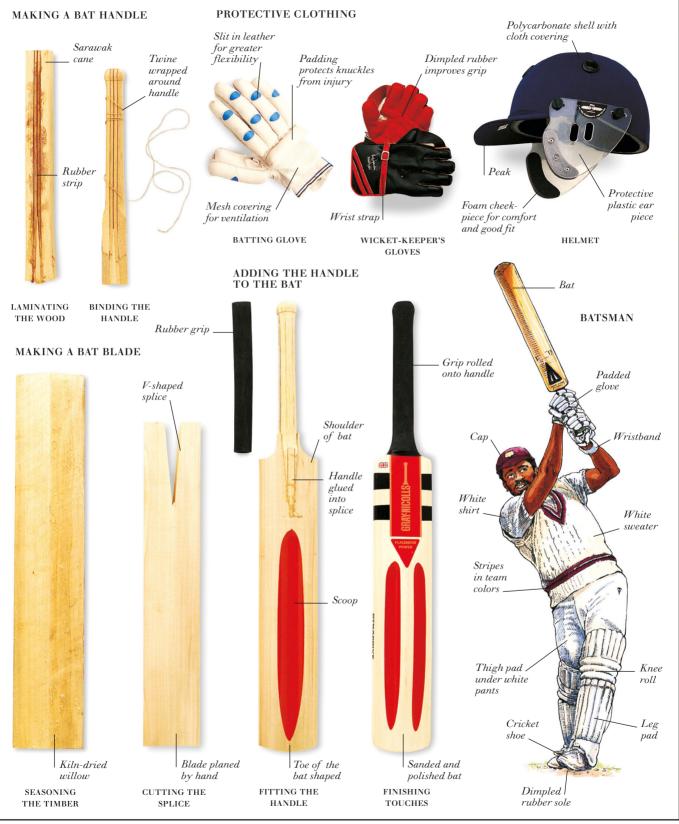


Cricket

CRICKET IS A BALL GAME PLAYED by two teams of eleven players on a pitch with two sets of three stumps (wickets). The bowler bowls the ball down the pitch to the batsman of the opposing team, who must defend the wicket in front of which he stands. The object of the game is to score as many runs as possible. Runs can be scored individually by running the length of the playing strip, or by hitting a ball that lands outside the boundary ("six"), or that lands inside the boundary but bounces or rolls outside FORWARD DEFENSIVE DEFENSIVE ("four"); the opposing team will bowl and field, attempting to dismiss the batsmen. STROKE STROKE A batsman can be dismissed in one of several ways: by the bowler hitting the wicket with the ball ("bowled"); by a fielder catching the ball hit by the batsman before it touches the ground ("caught"); by the wicket-keeper or another fielder breaking the wicket while the batsman is attempting a run and is therefore out of his ground ("stumped" or "run out"); by the batsman breaking Wicket-keeper the wicket with his own bat or body ("hit wicket"); by a part of the batsman's body being hit by a ball that would otherwise have hit the wicket ("leg before wicket" ["lbw"]). A match ON-DRIVE OFF-DRIVE consists of one or two innings and each inning ends when the tenth batsman of the batting team is out, when a certain number of overs (a series of six balls bowled) have been Batsman played, or when the captain of the batting team "declares" ending the innings voluntarily. Wicket Bowling POSSIBLE FIELD POSITIONS FOR AN AWAY SWING crease BOWLER TO A RIGHT-HANDED BATSMAN (IN RED) AND OTHER FIELD POSITIONS CRICKET PITCH PULL Long on Long off Umpire Bowler 66 ft Boundary line (20 m)Nonstriking Deep batsman mid-wicket Mid-on Extra Silly mid-on Mid-off Forward SQUARE CUT LEG GLANCE short leg Silly mid-off CRICKET BALL AND WICKET Square leg Cover Seam Leather Deep skin sauare Point BALL leg BailWICKET Square-leg Gulley umpire Third man Batsman Bowler Stump Long leg Second slip Return $Leg\ slip$ crease Wicket-keeper First slip UmpireNonstriking batsman

Sight screen

Fine leg

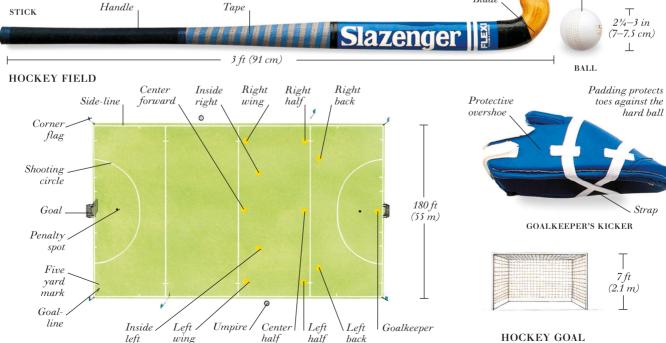


Field hockey, lacrosse, and hurling

ALL OVER THE WORLD, TEAM GAMES have evolved that require that a ball be struck or carried, and tossed at the end of a stick. Early forms of these games include hurling, shinty, bandy, and pelota. Field hockey is played by men and women: two teams of 11 players try to gain and keep possession of the ball and score goals by using the hockey stick to propel the ball into their opponents' goal net. Skills such as passing, pushing, or hitting the ball by slapping or lifting it in a flicking movement, and shooting at goal are crucial. Hockey is played indoors and outdoors on grass or synthetic fields. Lacrosse is played internationally as a 12-a-side game for women and as 10-a-side game for men. The women's field has no absolute boundaries but the men's field has clearly defined side-lines and end-lines. The ball is kept in play by being carried, thrown, or batted with the crosse, and rolled or kicked in any direction. In men's and women's lacrosse, play can continue behind the marked goal areas. Similar skills are required in hurling—a Gaelic field game played on the same field as Gaelic football (see pp. 528–529), using the same goalposts and net. In hurling, the ball may be struck with or carried on the hurley and, when off the ground, may be struck with the hand or kicked. Goals (three points) are scored when the ball passes between the posts and under the crossbar; one point is scored when it passes between the posts and over the crossbar.

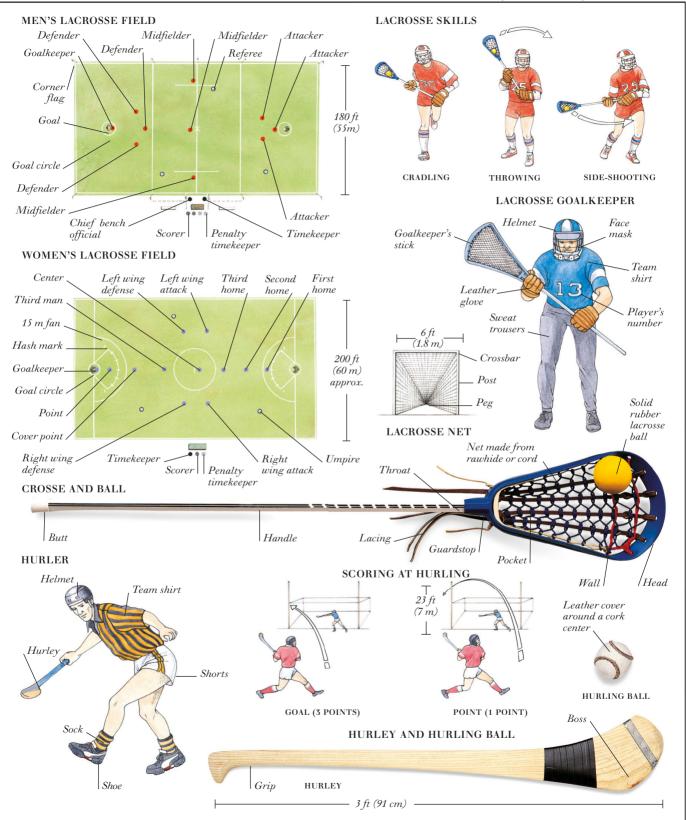
Air vent Hard. shell Face mask HELMET Strap Rigid palm Padded wrist Steam-bent ash head GAUNTLET Stitched seam Blade 23/4-3 in

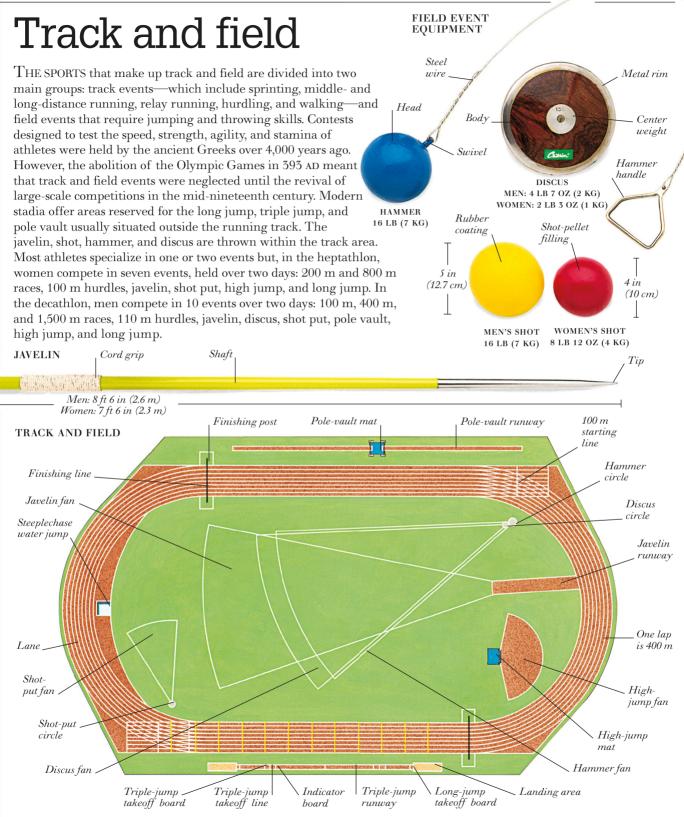
GOALKEEPER'S EQUIPMENT

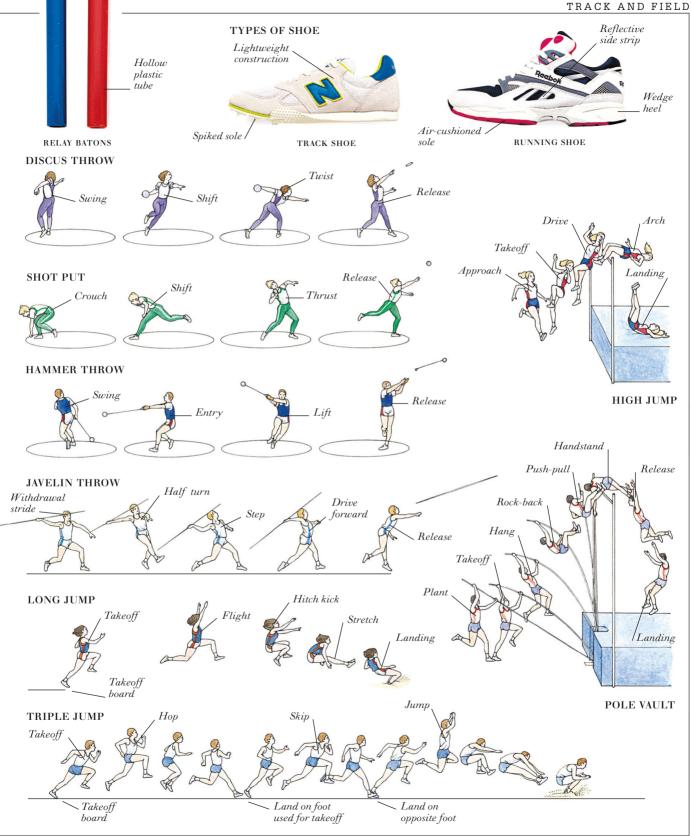


HOCKEY STICK AND BALL

Handle







Racket sports



PROTECTIVE EYEWEAR The object of all racket sports is to make shots the opponent cannot return. Games are played by two players (singles) or four players (doubles). Racket shape and size is tailored to each sport, but all rackets are constructed of wood, plastic, aluminum, or high-performance materials such as fiberglass and carbon graphite. Racket strings are usually

TENNIS RACKET

Frame

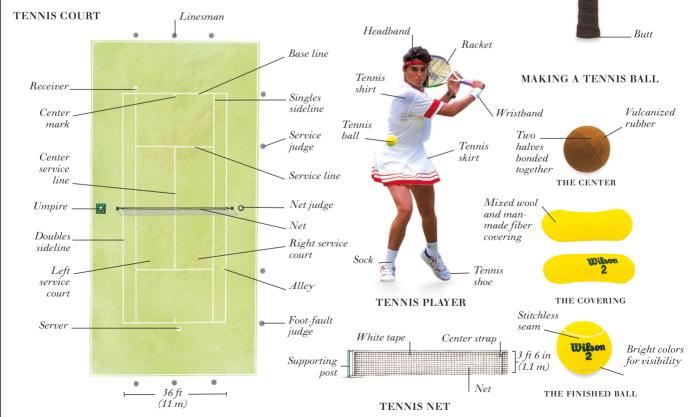
Throat

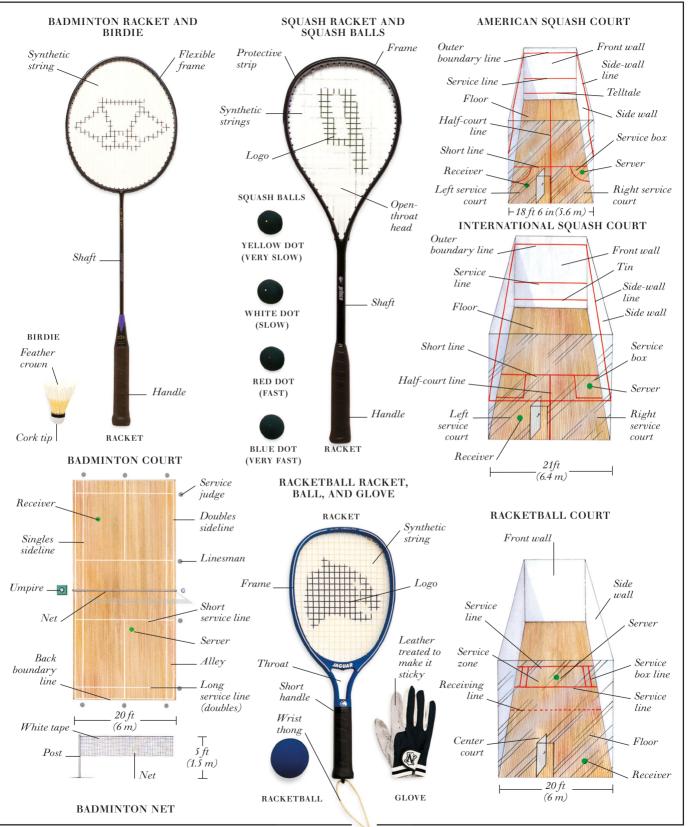
Grip

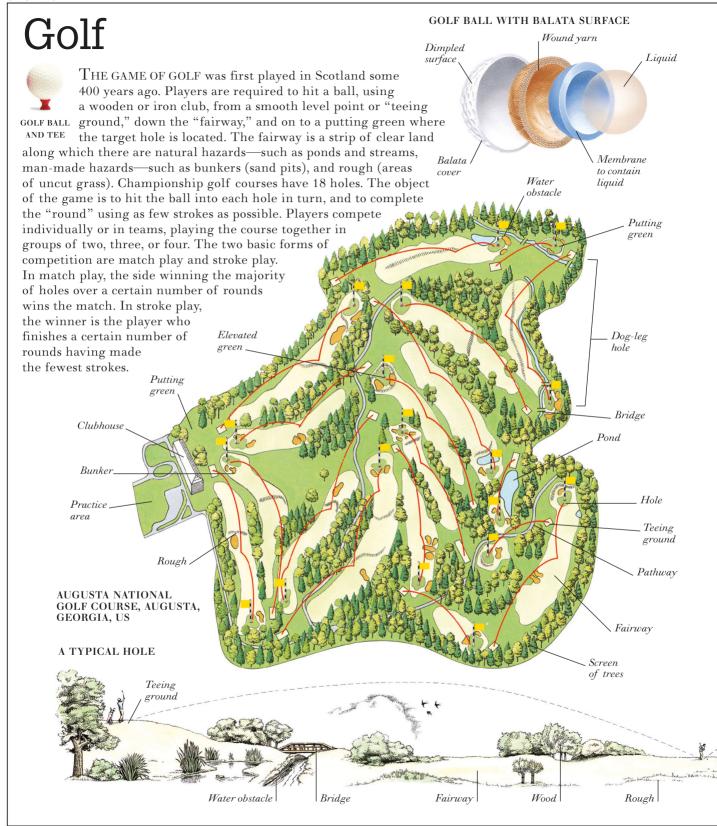
Synthetic string

Head

synthetic, although natural gut is still used. Tennis is played on a court divided by a low net. Opposing players serve alternate games. At least six games must be won to gain a set, and two or sometimes three sets are needed to win a match. Tennis courts may be concrete, grass, clay, or synthetic, each surface requiring a different style of play. Badminton is an indoor sport that is played with light, flexible rackets and a birdie on a court with a high net. Players can score points only on their serve. The first to reach 15 points (11 points for women's singles) wins the game. Two games are needed to win a match. Squash and racketball are both played in enclosed courts. One player hits the ball against the front wall, and the other tries to return it before it bounces on the floor more than once. Squash rackets have smaller, rounder heads and stiffer frames than badminton rackets. In the United States, the game is played on a narrower court than an international court using a much harder ball. Squash games are played to 15 points (American) or 9 points (international). In racketball, players use a ball that is larger and bouncier than a squash ball. The racket is thick and sturdy, with a large head, short handle, and a thong that loops around the wrist. Points can be won only when serving, and the first player to reach 21 points wins.



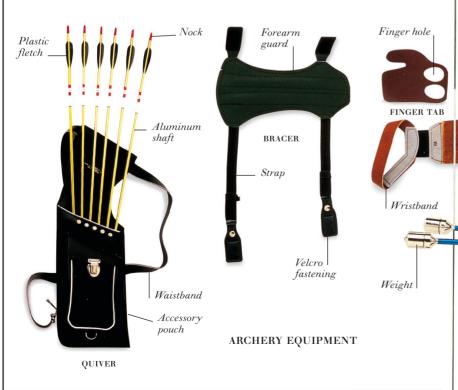


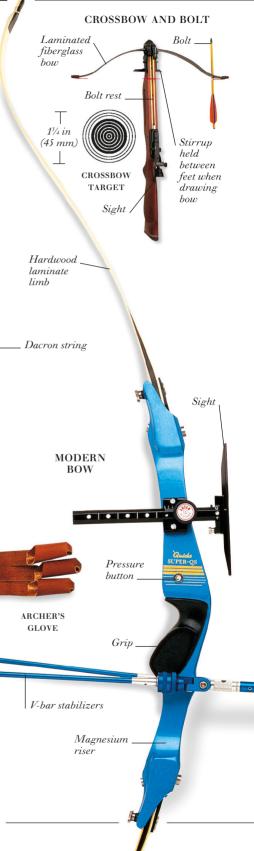




Archery and shooting

TARGET SHOOTING AND ARCHERY EVOLVED as practice for hunting and battle skills. Modern bows, although designed according to the principles of early hunting bows, use laminates, fiberglass, dacron, and carbon, and are equipped with sights and stabilizers. Competitors in target archery shoot over distances of 100 ft (30 m), 165 ft (50 m), 230 ft (70 m), and 300 ft (90 m) for men, and 100 ft (30 m), 165 ft (50 m), 200 ft (60 m), and 230 ft (70 m) for women. The closer the shot is to the center of the target, the higher the score. The individual scores are added up, and the archer with the highest total wins the competition. Crossbows are used in match competitions over 33 ft (10 m), and 100 ft (30 m). Rifle shooting is divided into three categories: smallbore, bigbore, and air rifle. Contests take place over a variety of distances and further subdivisions are based on the type of shooting position used: prone, kneeling, or standing. The Olympic biathlon combines cross-country skiing and rifle shooting over a course of approximately 12½ miles (20 km). Additional magazines of ammunition are carried in the butt of the rifles. Bigbore rifles fitted with a telescopic sight can be used for hunting and running game target shooting. Pistol shooting events, using rapid-fire pistols, target pistols, and air pistols, take place over 33 ft (10 m), 82 ft (25 m), and 165 ft (50 m) distances. In rapid-fire pistol shooting, a total of 60 shots are fired from a distance of 83 ft (25 m).

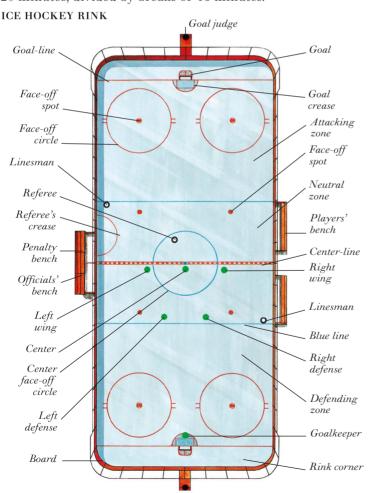






Ice hockey

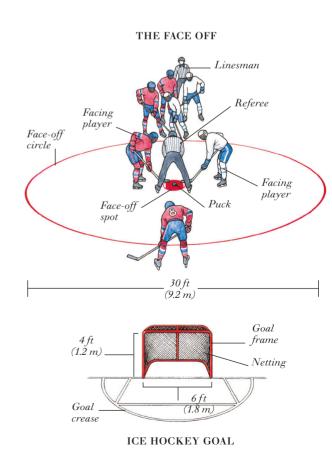
ICE HOCKEY IS PLAYED by two teams of six players on an ice rink, with a goal net at each end. The object of this fast, and often dangerous, game is to hit a frozen rubber puck into the opposing team's net with a ice hockey stick. The game begins when the referee drops the puck between the sticks of two players from opposing teams, who "face off." The rink is divided into three areas: defending, neutral, and attacking zones. Players may move with the puck and pass the puck to one another along the ice, but may not pass it more than two zones across the rink markings. A goal is scored when the puck entirely crosses the goalline between the posts and under the crossbar of the goal. A team may field up to 20 players although only six players are allowed on the ice at one time; substitutions occur frequently. Each game consists of three periods of 20 minutes, divided by breaks of 15 minutes.



85–100 ft (26–30 m)



GOALKEEPER





Alpine skiing

COMPETITIVE ALPINE SKIING is divided into four disciplines: downhill, slalom, giant slalom, and super-giant slalom (Super-G). Each one tests different skills. In downhill skiing, competitors race down a slope marked out by control flags, known as "gates," and are timed on a single run only. Competitors wear crash helmets, one-piece Lycra suits, and long skis with flattened tips Wrist strap to minimize air resistance. Slalom and giant slalom skiiers negotiate a twisting course requiring balance, agility, Ski pole and quick reactions. Courses are defined by pairs of Basket gates. Racers must pass through each pair of gates Ski boot to complete the course successfully. Competitors are Safety binding timed on two runs over different courses, and the skier who completes the courses in the shortest time wins. The equipment and protective guards used by slalom skiiers are shown opposite.

In Super-G races, competitors ski a single run that combines the technical challenge of slalom with the speed of downhill. The course requires skiers to complete medium-to-long radius turns at high speed, and contain up to two jumps. Clothing is the same as for downhill, but slightly shorter skis are used.



DOWNHILL SKIER

goggle

SAFETY BINDING

One-piece

lvcra ski

Helmet

Ski

glove

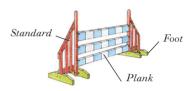


Equestrian sports

EOUESTRIAN SPORTS HAVE TAKEN place throughout the world for centuries: events involving mounted horses were recorded in the Olympic Games of 642 BC. Showjumping, however, is a much more recent innovation, and the first competitions were held at the beginning of the 1900s. In this sport, horse and rider must negotiate a course of variable, unfixed obstacles, making as few mistakes as possible. Showjumping fences consist of wooden stands, known as standards or wings, that support planks or poles. Parts of the fence are designed to collapse on impact, preventing injury to the horse and rider. Judges penalize competitors for errors, such as knocking down obstacles, refusing jumps, or deviating from the course. Depending on the type of competition, the rider with the fewest faults, most points, or fastest time wins. There are two basic forms of horse racing—flat races and races with jumps, such as steeplechase or hurdle races. Thoroughbred horses are used in this sport, since they have great strength and stamina and can achieve speeds of up to 40 mph (65 kph). Jockeys wear "silks"caps and jackets designed in distinctive colors and patterns that help identify the horses. In harness racing, the horse is driven from a light, two-wheeled carriage called a sulky. Horses are trained to trot and to pace, and different races are held for each of these types of gait. In pacing races, the horses wear hobbles to prevent them from breaking into a trot or gallop. Breeds such as the Standardbred and the French Trotter have been developed especially for this sport.



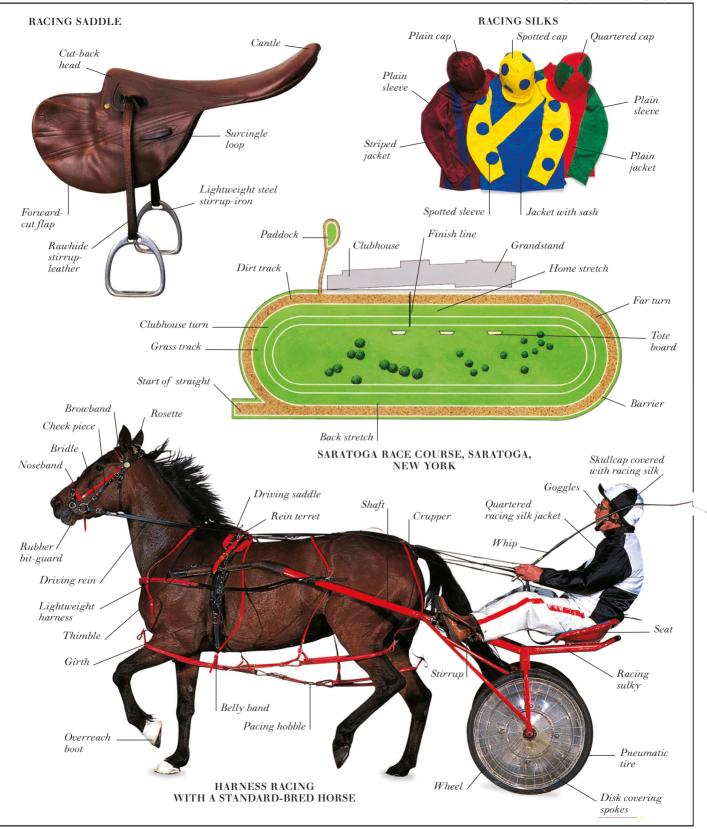
SHOWJUMPING FENCES



UPRIGHT PLANKS



Wooden block painted to resemble a brick



Judo and fencing

COMBAT SPORTS ARE BASED ON THE SKILLS used in fighting. In these sports, the competitors may be unarmed—as in judo and boxing—or armed—as in fencing and kendo. Judo is a system of unarmed combat developed in the East. Translated from the Japanese, the name means "the gentle way." Students learn how to turn an opponent's force to their own advantage. The usual costume is loose white pants and a jacket, fastened with a cloth belt. The color of belt indicates the student's level of expertise, from white-belted novices to the expert "black belts." Competitions take place on a mat or "shiaijo," 30 or 33 ft (9 or 10 m) square in size, bounded by "danger" and "safety" areas to prevent injury. Competitors try to throw, pin, or master their opponent by applying pressure to the arm joints or neck. Judo bouts are strictly monitored, and competitors receive points for superior technique, not for injuring their opponent. Fencing is a combat sport using swords, which takes place on a narrow "piste" 46 ft (14 m) long. Competitors try to touch specific target areas on their opponent with their sword or "foil" while avoiding being touched themselves. The winner is the one who scores the greatest number of hits. Fencers wear clothing made from strong white material that affords maximum protection while allowing freedom of movement, steel mesh masks with padded bibs to protect the fencer's neck, and a long white glove on their sword hand. Fencing foils do not have sharpened blades, and their tips end in a blunt button to prevent injuries. Three types of swords are used—foils, épées, and sabers. Official foil and épée competitions always use an electric scoring system. The sword tips are connected to lights by a long wire that passes underneath each fencer's jacket. A bulb flashes when a hit is made.

JUDO HOLDS AND THROWS



SIDE FOUR QUARTER HOLD



SINGLE WING



BODY DROP



ONE ARM SHOULDER THROW



SHOULDER WHEEL



SWEEPING LOW THROW

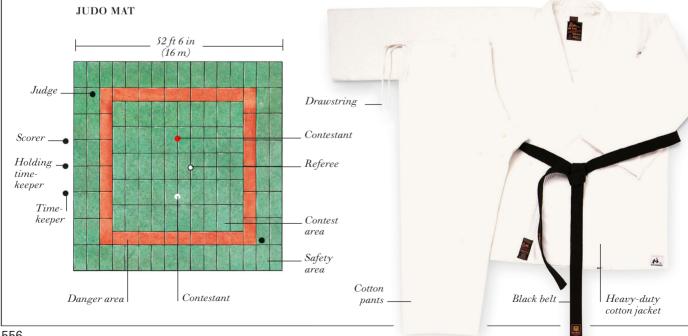


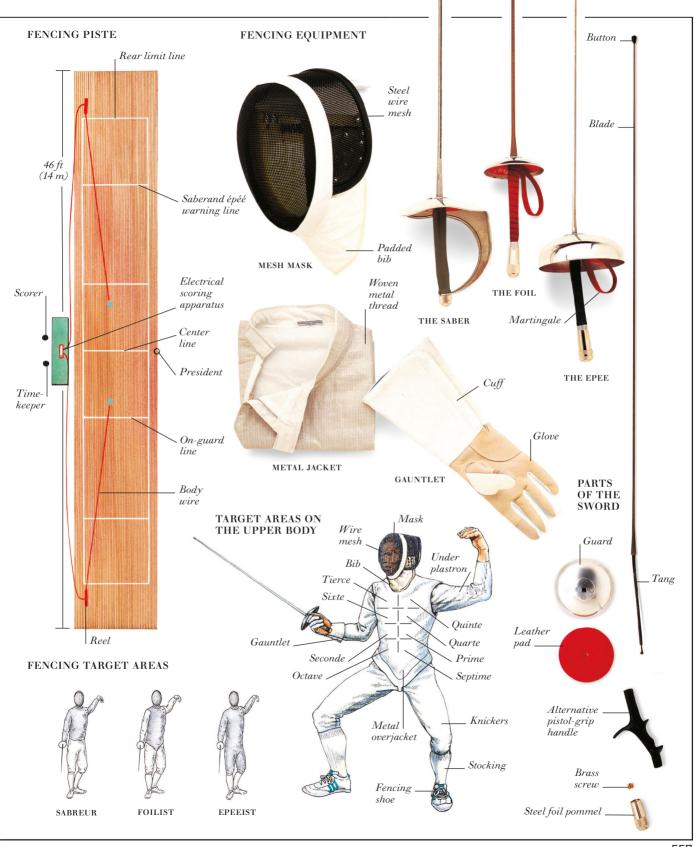
STOMACH THROW



KNEE WHEEL

UNIFORM





Swimming and diving

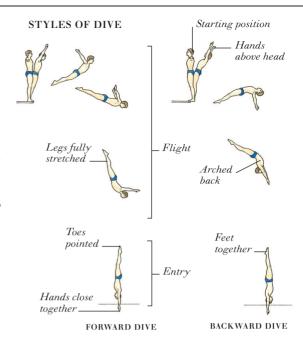


GOGGLES

558

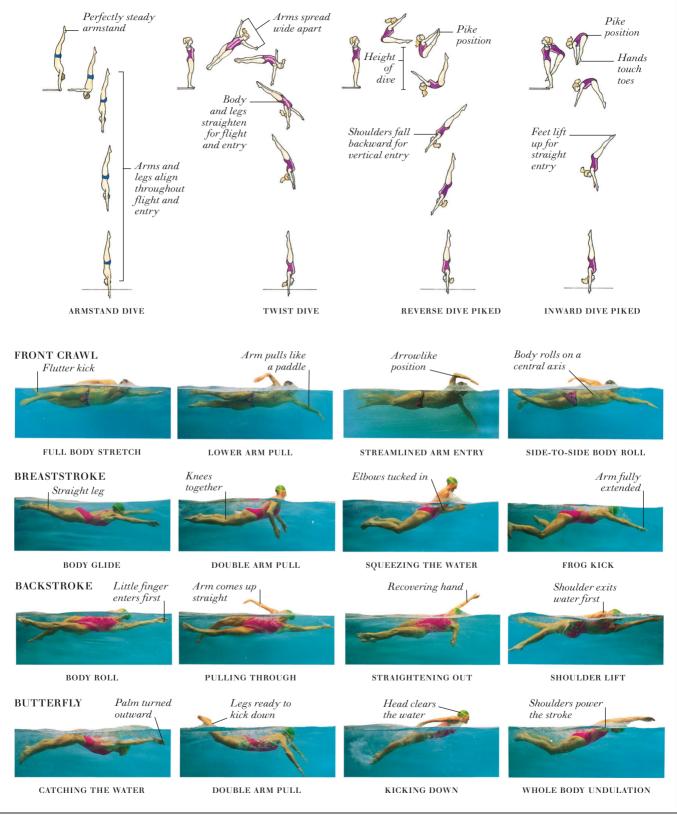
SWIMMING WAS INCLUDED in the first modern Olympic Games in 1896 and diving events were added in 1904. Swimming is both an individual and a team sport and races take

place over a predetermined distance in one of the four major categories of stroke—freestyle (usually front crawl), butterfly, breaststroke, and backstroke. Competition pools are clearly marked for racing and antiturbulence lane lines are used to separate the swimmers and help keep the water calm. The first team or individual to finish the race is the winner. Competitive diving is divided into men's and women's springboard and platform (highboard) events. There are six official groups of dives: forward dives, backward dives, armstand dives, twist dives, reverse dives, and inward dives. Competitors perform a set number of dives and after each one a panel of judges award marks according to the quality of execution and the degree of difficulty.



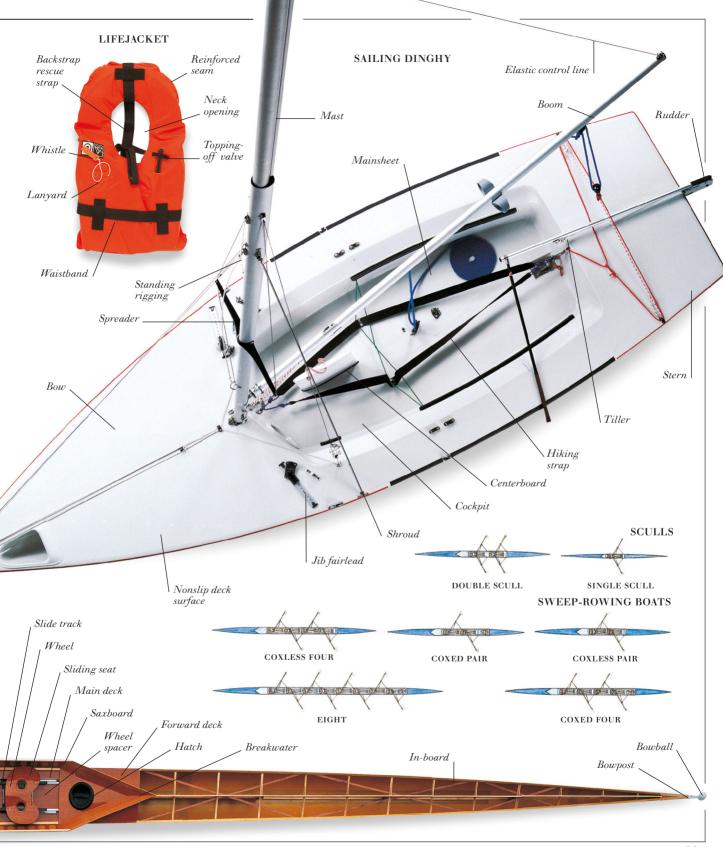
SWIMMING POOL

Swimmer Lane Starting number block Lane timekeeper Chief timekeeper. End wall Latex rubber Placing molds to shape judge Starter of head SWIMWEAR Side Recorder wall High neckline Backstroke marker 49 ft (15 m) from Anti-Rubberend of pool turbulence covered lane line Referee Stroke Molded. judge rubber Man-made stretch Backstroke fabric turn indicator EARPLUG 16 ft (5 m) from $end\ o \ \ f\ pool$ Drawstring Bottom High-cut line leg Turning Turning wall judge Strong seam 75 ft 6 in (23 m) SWIMSUIT TRUNKS



560

SAILING GEAR Canoeing, rowing, Buoyancy Sleeveless aid and sailing long johns WATERBORNE SPORTS are as varied as the crafts used. There are two disciplines in rowing; sweep rowing, in which each rower has one oar, and sculling, in which rowers use two oars. There are a number of different Olympic and competitive rowing events for both men and women. The number of rowers and weight classes Long-sleeved vary. Some rowing events use a coxswain; a steersman jacket who does not row but directs the crew. Kavaks and canoes are used in straight sprint and slalom races. Slalom races Neoprene take place over a course consisting of 20 to 25 gates, material including at least six upstream gates. In yacht racing, competitors must complete prescribed courses, organized by the race committees, in the shortest possible time, using sail power only. Olympic events include classes for keel boats, dinghies, and catamarans. GLOVE Bootlace ONE-PERSON KAYAK AND PADDLE Ribbed Blade RimShaft Nonslip sole Back strap воот Cockpit High density SternRight rail polythene Nose cone Toggle Bow Adjusting Left rail screw SeatCockpit rim Gate clamp SINGLE SCULL AND OARS (WITH CLOTH DECKING REMOVED) Blade Colors SpoonStroke-side Shaft Rigger Sycamore Stretcher Loomheam Grip Bow-side Button Water shoot Keel Shoe Diagonal Bung Aft shoulder frame Aluminum beam Spruce beam Sternpost Kelson (keelson)



ANGLING MEANS FISHING WITH A ROD, reel, line, and lure. There are several different types of angling: freshwater coarse angling, for members of the carp family and pike; freshwater game angling, for salmon and trout; and sea angling, for sea fish such as flatfish, bass, and mackerel. Anglers use a variety of methods for catching fish. These include bait fishing, in which bait (food to allure the fish) is placed on a hook and cast into the water; fly fishing, in which a natural or artificial fly is used to lure the fish; and spinning, in which a lure that looks like a small fish revolves as it is pulled through the water. The angler uses the rod, reel, and line to cast the lure over the water. The reel controls the line as it spills off the spool and as it is

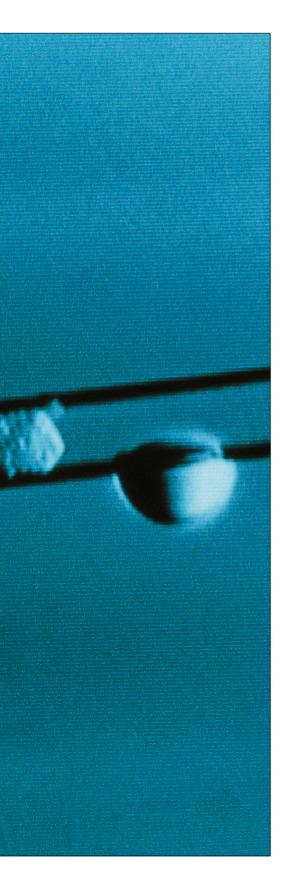
wound back. Weights may be fixed to the line so that it will sink. Swivels are attached to prevent the line from twisting. When a fish bites, the hook must become embedded in its mouth and remain there while the catch is reeled in.











The Modern World

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Personal computer

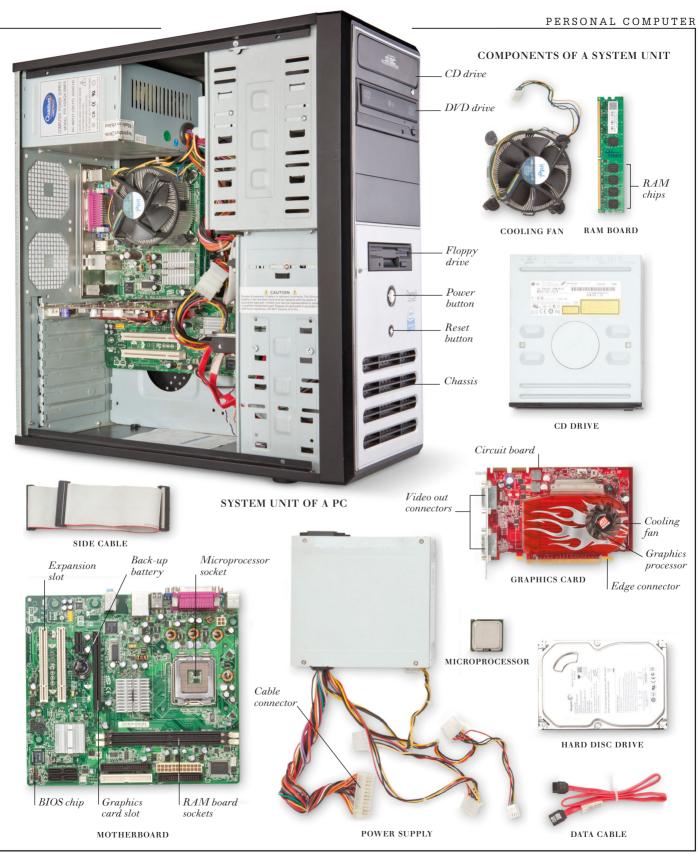
Personal computers (PCs) fall into two main types: IBM-compatible PCs, known simply as PCs, and Apple Macintosh PCs, known as "Macs." They differ in the way files LEDbacklit and programs, and the user's access to them, glossy are organized, and programs must be tailored widefor each type. However, in most other respects screen PCs and Macs have much in common. Both contain microchips, or integrated circuits, that store and process data. The "brain" of any PC is a chip known as the central processing unit (CPU), which performs mathematical operations in order to run program instructions and receive, store, and output Keyboard Mouse data. The most powerful personal computer CPUs today can perform more than a billion calculations a second. Data can be input via CDs, USB memory sticks, and iMAC other storage media. Highly portable laptop and network PCs are also in widespread use. Most PCs are able to communicate with many other devices, including digital cameras (see pp. 580-81) and smartphones USB ports (4) (see pp. 588-89). Audio in jack Webcam Headphone jack Powercord Firewire connector 800 port REAR OF **iMAC** Mini display port Ethernet LCDdisplay Optical drive Power connector Keyboard USB ports (2) Touchpad Expansion port Remote control Display Fingerprint Digital media slot reader Security Left Right RG-45 HDMIeSATA/ cable slot Headphone touchpad touchpad (network) port USB port port button button jacks (2) External

monitor port

SIDE VIEW OF HP PAVILION DV4 LAPTOP

HP PAVILION DV4 LAPTOP

Audio in jack



Handheld computer

Sleep/wake button

By the Early 1990s electronic circuitry had been miniaturized to such an extent that it was possible to make small handheld computing devices. The first of these was the Personal Digital Assistant (PDA), which offered features including an address book, calendar, and notepad. In recent years, PDAs have been overtaken by smartphones with internet and email access (see pp. 588-589). A related product is the e-book reader, which stores books in digital form and uses "electronic paper" to mimic the appearance of ink on real paper. An e-book reader no bigger than a thin paperback can store several thousand digital books in its memory. The most recent small computing device is the handheld computer. This looks like a thin flat display, but it is actually a complete computer. Handheld computers are typically controlled by a touch-sensitive screen and have a wireless link to other computers and the internet. They run software applications, or apps, downloaded from the internet. The most popular handheld computer currently is the Apple iPad. It has a multitouch interface that enables its screen to detect the movements of fingertips. In addition to selecting options and apps by touching the screen, images can be enlarged or shrunk by moving fingertips apart or together on the screen.



Touch data is sent as a list of finger positions to the controller where the information is used to zoom in and out of a web page

Touchscreeen electronics interpret the

outputs from the

grid to work out

MULTITOUCH INTERFACE

exactly where the fingers are Fingers alter the electric field around nearby sections of the grid

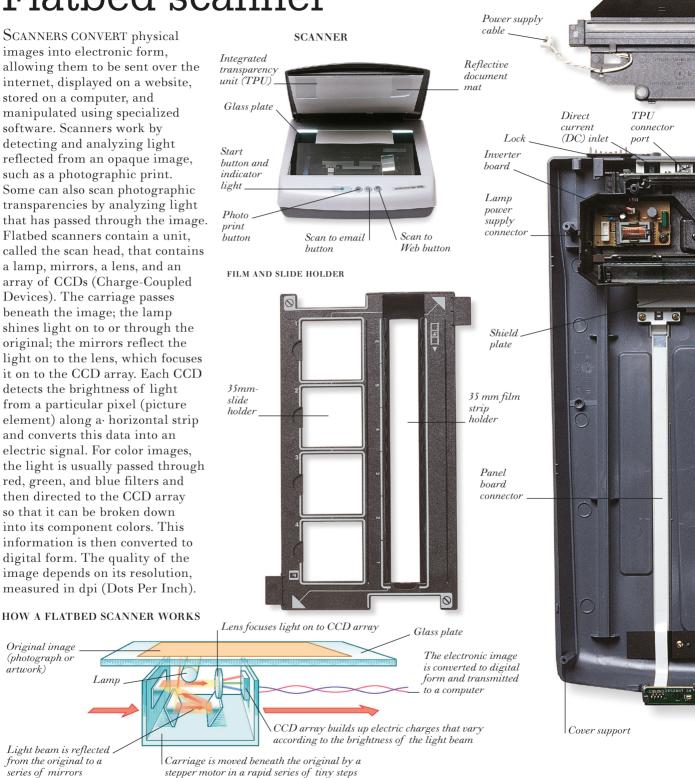


Controller.



Flatbed scanner

SCANNERS CONVERT physical images into electronic form, allowing them to be sent over the internet, displayed on a website, stored on a computer, and manipulated using specialized software. Scanners work by detecting and analyzing light reflected from an opaque image, such as a photographic print. Some can also scan photographic transparencies by analyzing light that has passed through the image. Flatbed scanners contain a unit. called the scan head, that contains a lamp, mirrors, a lens, and an array of CCDs (Charge-Coupled Devices). The carriage passes beneath the image; the lamp shines light on to or through the original; the mirrors reflect the light on to the lens, which focuses it on to the CCD array. Each CCD detects the brightness of light from a particular pixel (picture element) along a horizontal strip and converts this data into an electric signal. For color images, the light is usually passed through red, green, and blue filters and then directed to the CCD array so that it can be broken down into its component colors. This information is then converted to digital form. The quality of the image depends on its resolution, measured in dpi (Dots Per Inch).



Original image

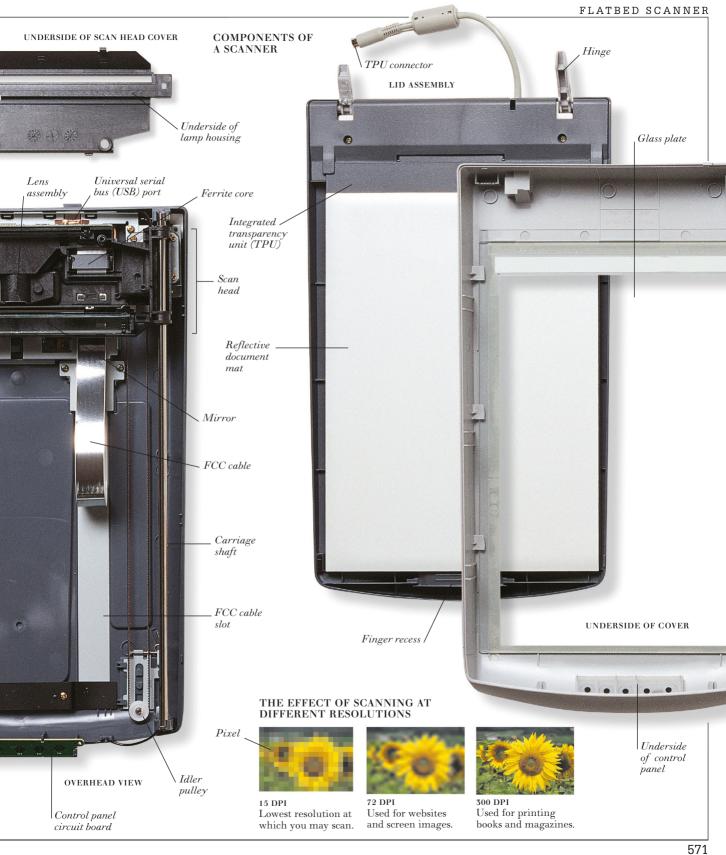
(photograph or

Light beam is reflected

from the original to a series of mirrors

Lam

artwork)



Airbus 380

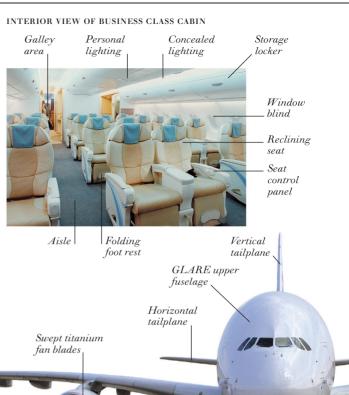


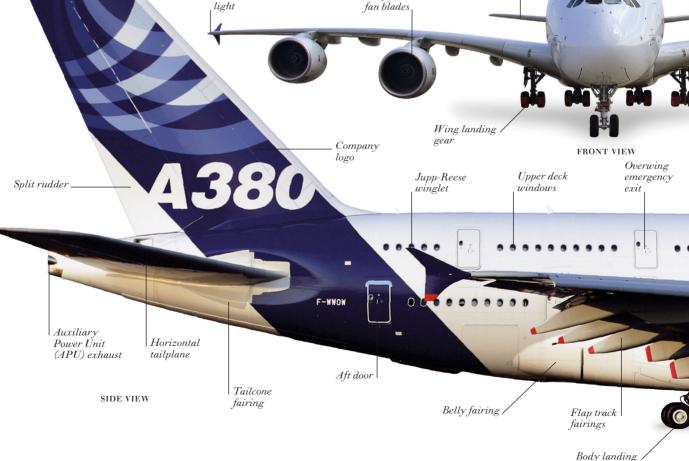
CROSS-SECTION OF FUSELAGE

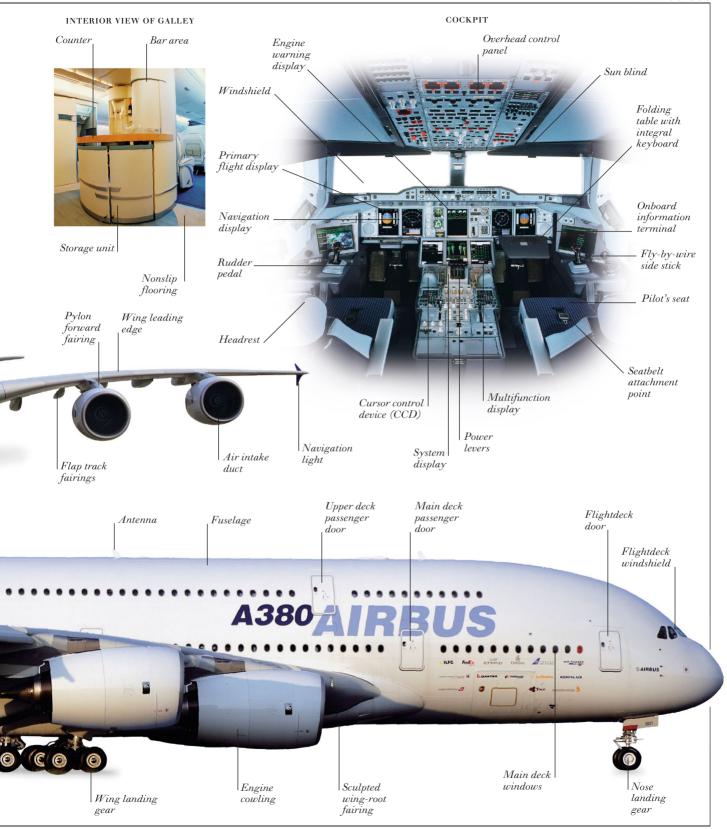
The Airbus A380 was conceived in the early 1990s to compete with, and if possible replace, the Boeing 747. Work began in earnest on what was then called the A3XX in 1994. Its maiden flight was in April 2005. The A380's shape is subtly molded to minimize drag from its ovoid fuselage. The structure makes extensive use of

Obstruction

composite materials, such as thermoplastics and GLARE (aluminum and glass fiber). Its engines are very powerful, but also very efficient. It is claimed that when carrying 550 passengers, the A380 uses only ¾ gallon (2.9 liters) of fuel per passenger per 60 miles (100 km).







Inkjet printer

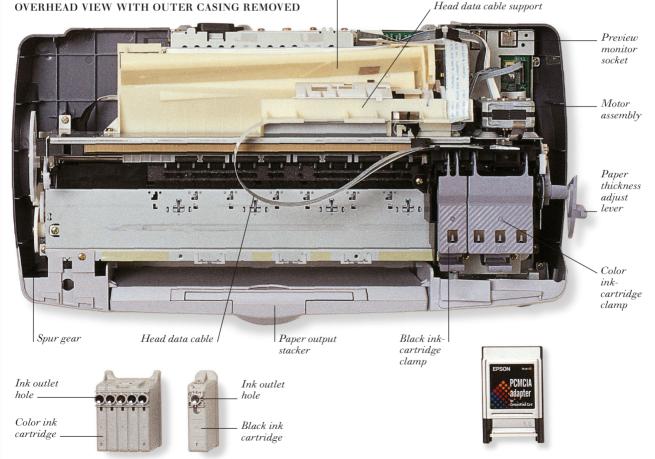
INKJET PRINTERS EXPEL ink droplets from hundreds of tiny jets, or nozzles, on to a medium, such as paper. to print an image. Each droplet corresponds to a single pixel (picture element). Black-and-white printers use only black ink, while color printers overprint combinations of the printing colors (cyan, yellow, magenta, and black) to create a full color range. The printhead containing the nozzles moves sideways across the paper, creating a line of pixels, before the paper moves slightly forward so the next line can be printed. Two basic methods are used to eject ink: thermal, in which ink is heated to form an expanding bubble that expels a droplet from the nozzle, and piezoelectric, in which an electric current expands a crystal causing it to push out the ink droplet. The printer shown here can print digital photographs directly from a memory card.

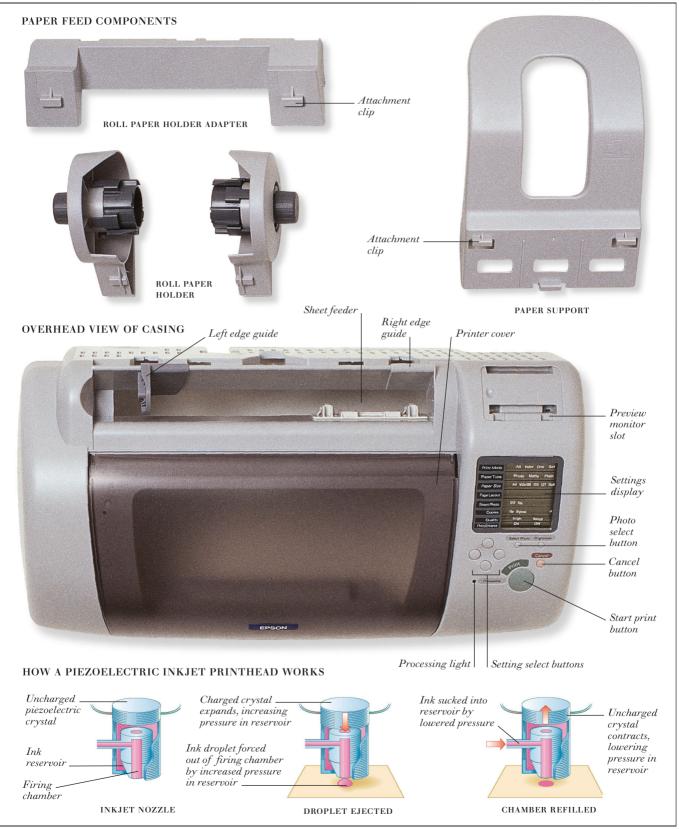
INK CARTRIDGES

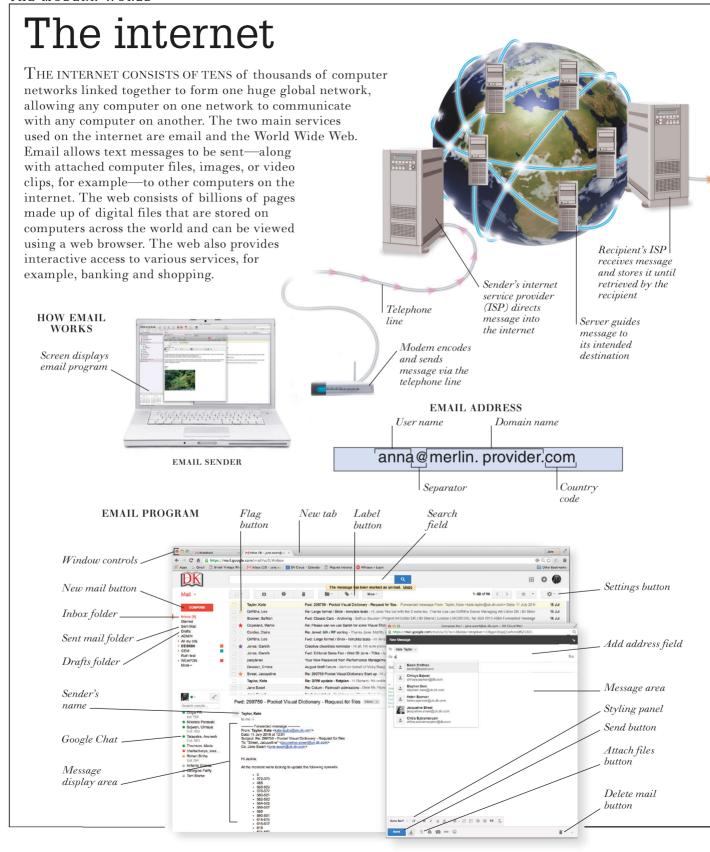
EPSON STYLUS PHOTO 895 COLOR INKJET PRINTER

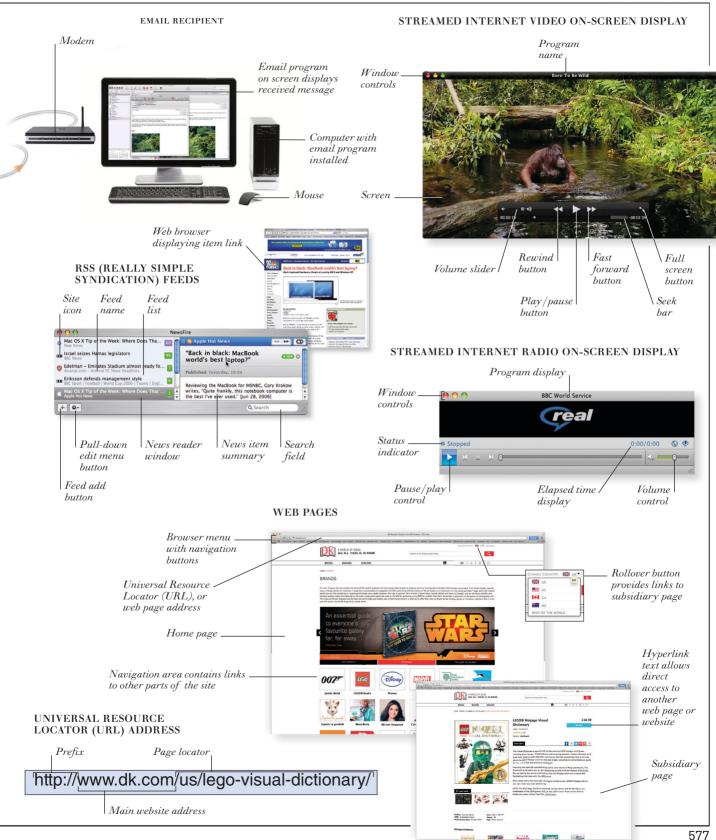


PC CARD ADAPTER









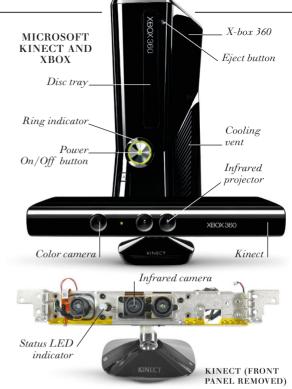
Electronic games



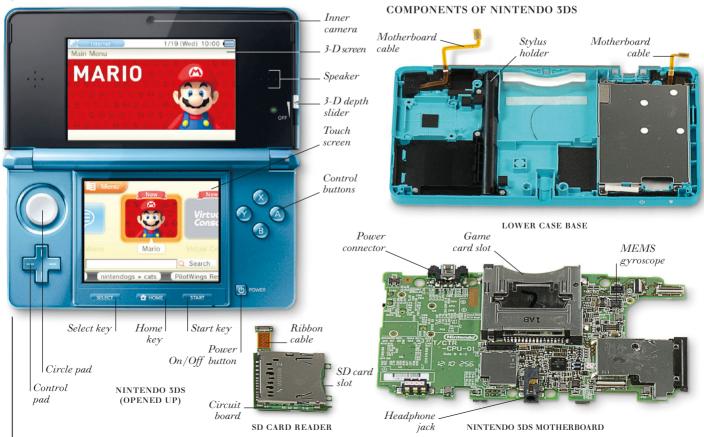
MARIO SPORTS MIX WII

VIDEO GAMES HAVE BEEN around since the early 1970s. They are played on PCs, arcade machines, on a TV using a home console, and on portable handheld consoles. Players use devices such as joysticks and control pads with buttons to control movement and action on screen.

The latest generation of consoles uses motion sensor technology to allow players to manipulate objects on screen by simply moving the controller. The most advanced game systems respond to gestures and commands spoken by a player, without any need to use a hand controller. The game itself is stored in the form of digital information on CD, DVD, or microchip—which may be integral or stored in a removable cartridge—or on an internal hard disk. A central processing unit (CPU) (see pp. 566–567) is needed to process commands from the players, while specialized graphics chips are used to process the complex mapping and texturing functions that make modern games appear so realistic.



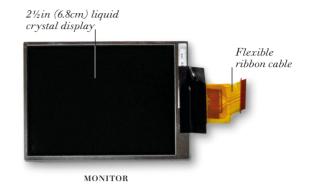
NINTENDO 3DS

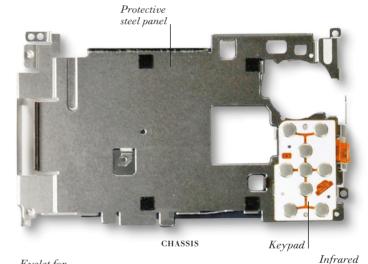




Digital camera

FOR MORE THAN 200 YEARS, CAMERAS recorded pictures as chemical changes in silver-containing substances, on a strip of flexible, celluloid film. The digital camera records pictures in electronic form. At its heart is a specialized integrated circuit known as a charge-coupled device (CCD). This has millions of microunits known as pixels. It works in the opposite way from a miniature computer or TV screen. Instead of electric signals making pixels shine, when light hits a pixel it generates a tiny electrical signal, according to the light's color and brightness. The signals from the CCD's millions of pixels are analogue: they vary continuously in a wavelike fashion. They are converted by a microchip to digital codes of numbers, represented as on-off electronic pulses. The digital signals are processed and fed to the camera's internal memory or a removable memory device such as a data card or memory stick. Photographs can be downloaded from a digital camera to a computer via a cable or in some cases a wireless link. Some digital cameras automatically reduce blurring caused by camera shake or fast movement, some can record video clips as well as still pictures.









582

Digital video camera

A VIDEO CAMERA, OR CAMCORDER, COMPONENTS OF A JVC EVERIO VIDEO CAMERA records a scene as a sequence of 25 or 30 still images per second, along with sound. It comprises a video camera to capture light from the scene, a viewfinder through which the scene Everio may be viewed, a screen on which the recorded scene may be viewed, a charge-coupled device (CCD) to convert the visual data into an electric signal, and a means of storing the signal. Digital video cameras convert the signal into digital form—a series of separate measurements MONITOR SHELL of the initial analogue (continuously varying) signal. They record the digital signal, usually on a chip or hard disk. Video cameras often have a slot where a memory card can be inserted MONITOR MOUNT to expand the memory and store longer recordings or more still pictures. Screen connector MONITOR FRAME Speaker $2^{3}/4$ -in (6.8-cm) LCD screen Play button Auto/Manual recording button Info button OK button MONITOR SCREEN Menu button Grip belt AV terminal Battery LEFT SIDE Power/ Charge lamp Power/charge lamp Access lamp Access lamp Zoom select lever LEFT OUTER Lens cover SHELL LCD monitor MicrophoneTOP VIEW LENS COVER ASSEMBLY



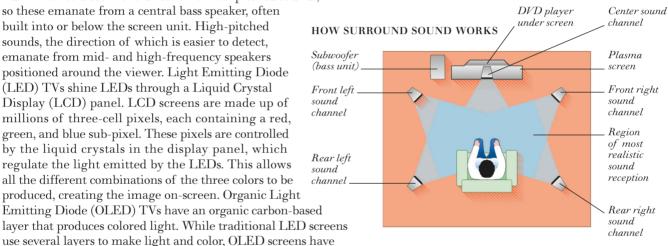
Home cinema

HOME CINEMA REPLICATES a real "movie theatre" using pictures displayed on a high-quality widescreen television set, such as an LED TV, and surround sound from strategically sited loudspeakers. The source for sound and vision is a DVD (Digital Versatile Disc). Its player uses standard CD (Compact Disc) digital technology, but with a higher density of laser-read microscopic pits—more than 20 billion such pits in multi-level spiral tracks that, stretched out, would extend nearly 25 miles (40km). Blu-ray is a high-quality DVD system that fits much more data on its disc than standard DVDs, allowing High Definition video files to be stored. It is hard for the human ear to discern the direction of low-pitched sounds, so these emanate from a central bass speaker, often built into or below the screen unit. High-pitched

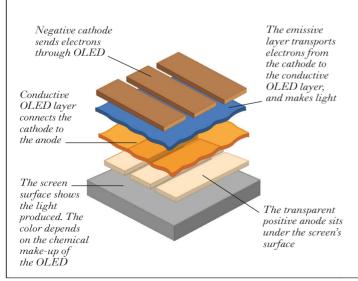
sounds, the direction of which is easier to detect, emanate from mid- and high-frequency speakers positioned around the viewer. Light Emitting Diode (LED) TVs shine LEDs through a Liquid Crystal Display (LCD) panel. LCD screens are made up of millions of three-cell pixels, each containing a red, green, and blue sub-pixel. These pixels are controlled by the liquid crystals in the display panel, which regulate the light emitted by the LEDs. This allows all the different combinations of the three colors to be produced, creating the image on-screen. Organic Light Emitting Diode (OLED) TVs have an organic carbon-based

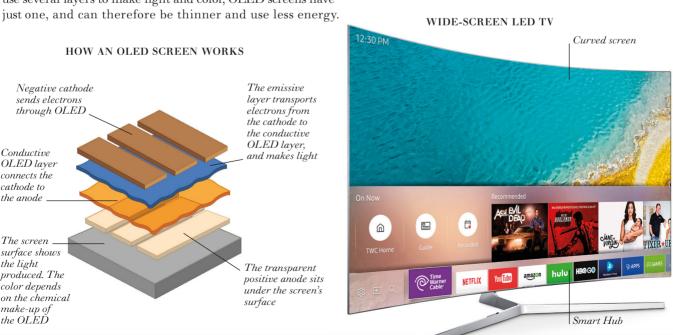
BLU-RAY PLAYER

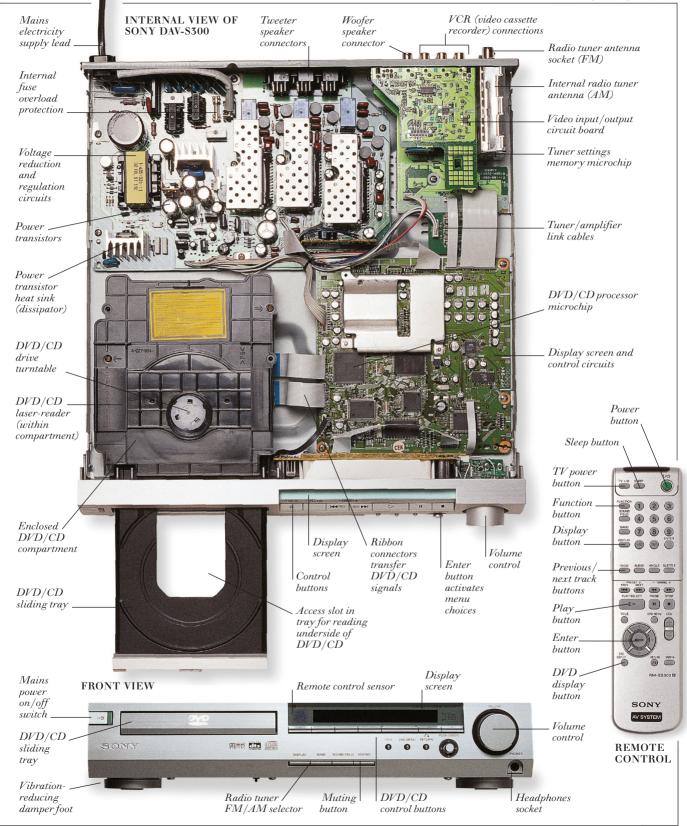




HOW AN OLED SCREEN WORKS









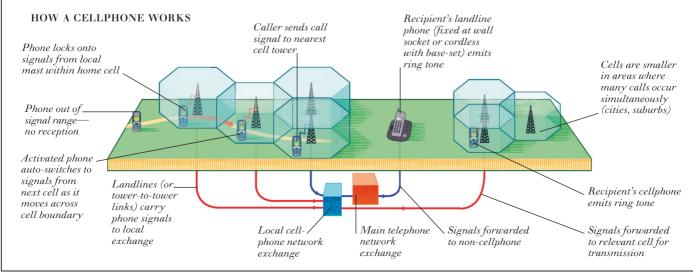


Cellphones

IN THE EARLY 1990s, THE CELLPHONE (or mobile phone) was a rare luxury, but in recent years it has outsold almost every other electrical gadget as a professional tool, domestic convenience, and even a fashion accessory. Cellphones have also generally shrunk in size, due to improvements in rechargeable batteries, which now store more electricity for longer in a smaller package, and to smaller, more efficient electronics that use less electricity. A "cellphone" is basically a low-power radio receiver-transmitter, plus a tiny microphone to convert sounds into electrical signals, and a small speaker that does the reverse. When the cellphone is activated, it sends out a radio signal that is answered by nearby mast transmitter-receivers. The phone locks onto the clearest signal and uses this while within range (the range of each transmitter is known as a cell). The phone continuously monitors signal strength and switches to an alternative transmitter when necessary. The phone's liquid crystal display (LCD) shows numbers, letters, symbols, and color pictures. Newer models have a larger screen for more complex color images, and commonly incorporate a camera, radio, and MP3 functionality. Smartphones, which are increasingly widespread, contain additional software and more may be downloaded. Smartphones typically offer internet and email access, PDA-like functions (see pp. 568-569), and may even contain GPS navigation software.



I-PHONE 6





Wearable technology

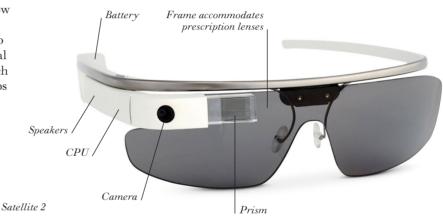
WEARABLE TECHNOLOGY DEVICES are clothing or accessories, such as jewelery or glasses, that have connected computer devices incorporated in their design. Such devices contain many smart sensors and are connected wirelessly—either via the internet or Bluetooth—to another device, such as a smartphone, that tracks the data the wearable device collects. Wearable technology has been around since the late 1970s, with devices such as the calculator watch and digital hearing aid. However, progress in wearable technology advanced rapidly in the early twenty-first century, when sensors and chip sets became much cheaper and more readily available. Wearable technology can have many different functions. Some devices are used to track medical data, such as measuring heart rate, breathing patterns,

and temperature. Others are used to monitor fitness, with many using GPS (below) to track how many steps a user has walked, or how many miles they have run, for example. Some wearable technology is designed to merge the digital world with the physical world—for example, Google Glass, which projects digital information, such as maps and text notifications, onto the glasses' screen without obstructing the view of the real world.

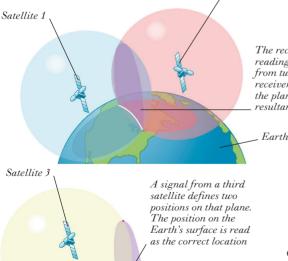


PEBBLE

GOOGLE GLASS



HOW GPS WORKS



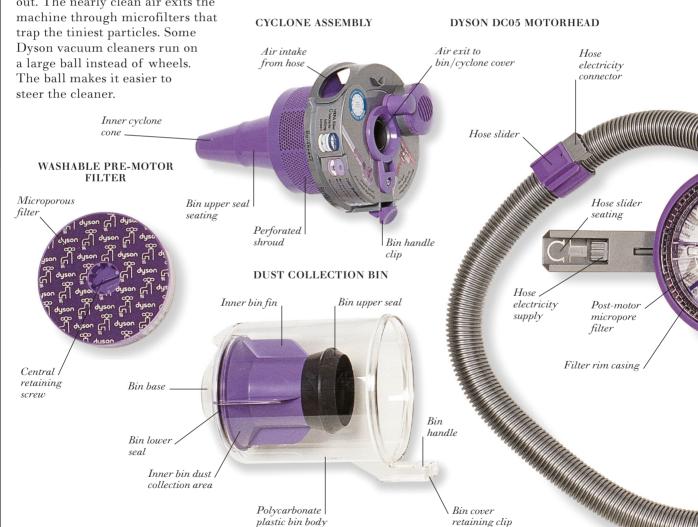
The receiver takes a reading of its distance from two satellites. The receiver is located along the plane where the two resultant spheres meet





Vacuum cleaner

In a conventional vacuum cleaner, an electric motor spins a fan that sucks in air carrying dust and debris. The air is forced through tiny pores in a dust bag, trapping most particles. In the 1990s, James Dyson's dual cyclone "bagless" design did away with the dust bag—and the reduced airflow caused by clogging of its pores. An electrically driven fan creates a partial vacuum within the machine. This sucks air into the machine past a rotating brush that loosens dirt. The air flows into a cylinder-shaped bin. As the air whirls around the bin like a miniature storm, or cyclone, larger particle are flung outward and fall to the bottom of the bin. The air then passes through perforations into a cone-shaped inner bin and then into a series of smaller cones, spinning faster all the time and flinging smaller and smaller particle out. The nearly clean air exits the



Wand handle and brushbar controls

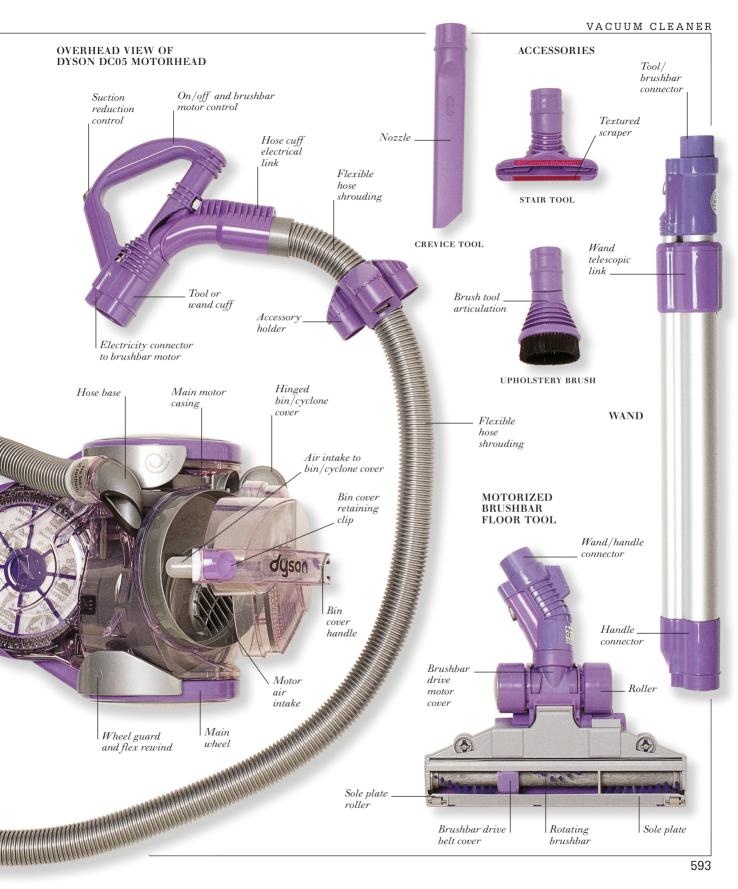
Lower wand

Motorized

brushbar

floor tool

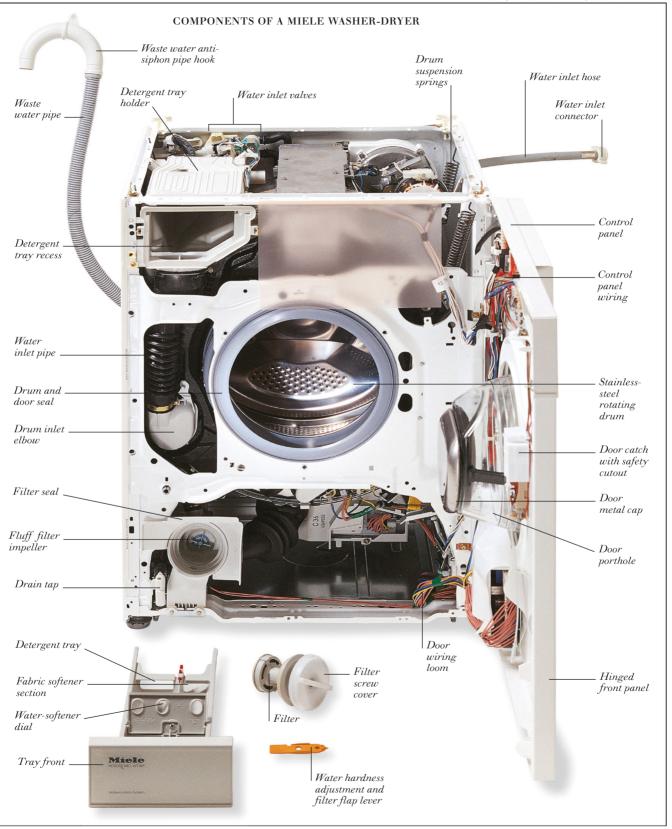
Upper wand



594

Iron and washer-dryer

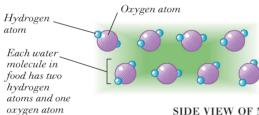
IN THE DAYS BEFORE WASHING MACHINES, laundry was done by hand— FRONT VIEW OF A MIELE WASHER-DRYER washed in a barrel, squeezed in a roller-mangle, hung on a line, and smoothed with an iron heated on the stove. In the 1880s, electrically Detergent heated irons were one of the first home electrical appliances. Today's tray iron still applies heat, sometimes moistened with steam, to dampen Controland flatten garment fibers. Machines with electric heaters and motors panels took the strain out of washing from the 1910s. Up to the 1960s, three machines were needed to wash, spin, and dry. Now clothes are Door swirled in a rotating ribbed tub of hot water, then spun fast to throw off most of the water, before slowly tumbling in electrically heated Filter air to dry—all in one appliance. flap COMPONENTS OF A STEAM IRON Nose Steam Spray Steam barrel barrel control Steam Spray Spray knobrelease Spray nozzle nozzle Noseactivator pump aperture Heating elements Water Soleplate tank surround Pilot light Handle Temperature and steam control dial Power spade SIDE VIEW OF STEAM IRON contacts Flex kink guard Steam control knobGrounding Pilotwire light Spray and supply steam knobs Securing screw Power wire mounting supply Temperature and cordsteam control dial Heel molding Water tank Flex clamp Flex cord Soleplate



Microwave combination oven

Conventional ovens use electrically warmed elements or a flame to heat food. In a microwave oven heat energy is created by electromagnetic waves produced by a magnetron and led by waveguides into the oven compartment. These microwaves cannot pass through the compartment's metal casing, being reflected within and spread evenly by a fan. But they do pass through most types of plastic, ceramics, and glass. Therefore platters or containers made from these materials are suitable for use in microwave ovens A combination oven also has conventional heating elements, to grill and "brown" in the traditional fashion, either alone or in conjunction with microwaves.

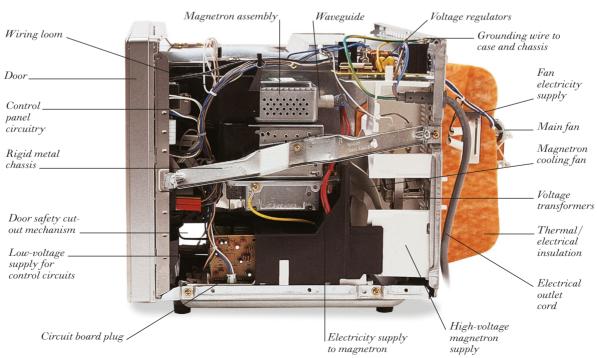
HOW MICROWAVES HEAT FOOD

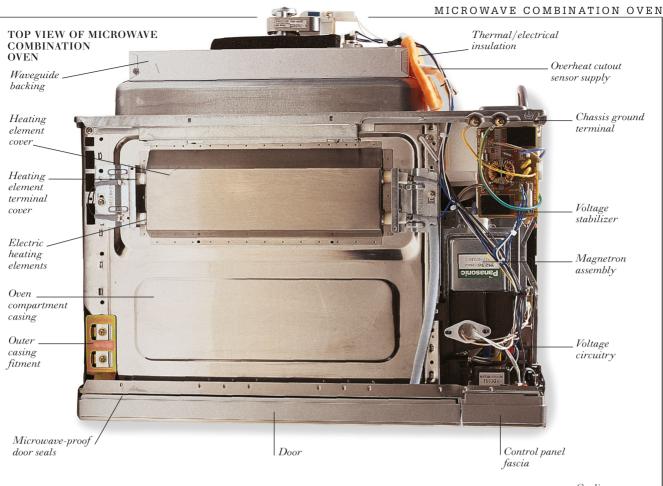


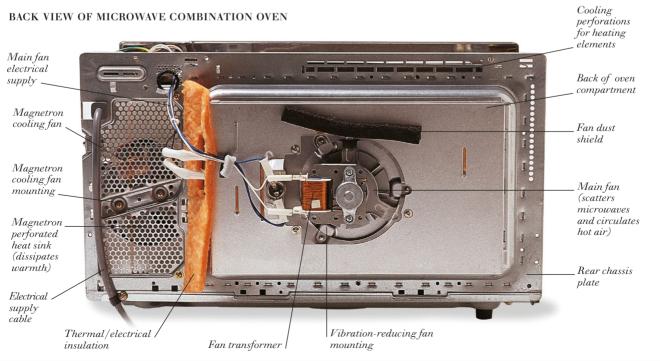
MICROWAVE COMBINATION OVEN

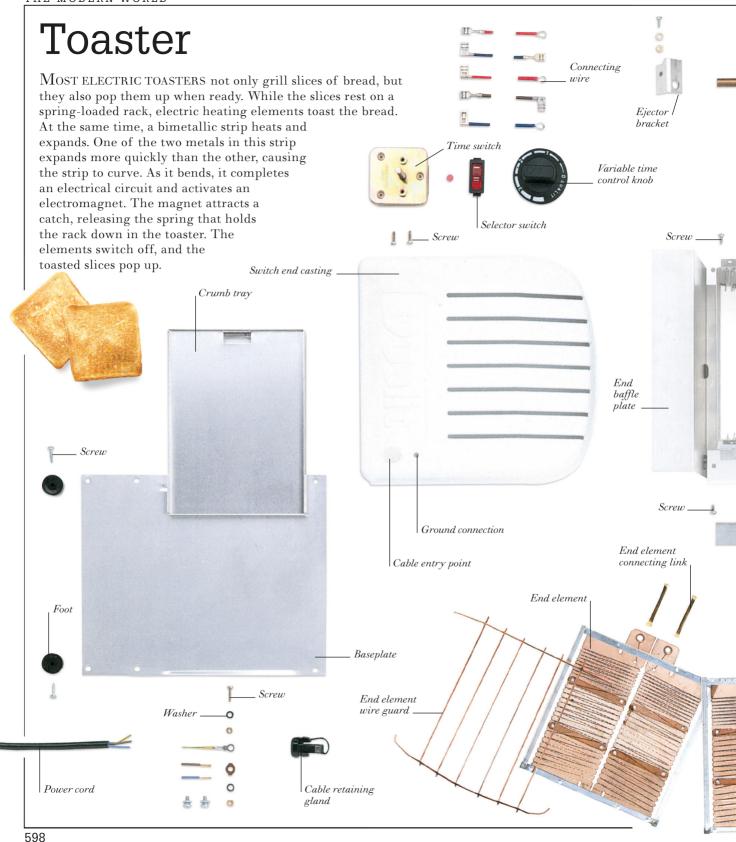


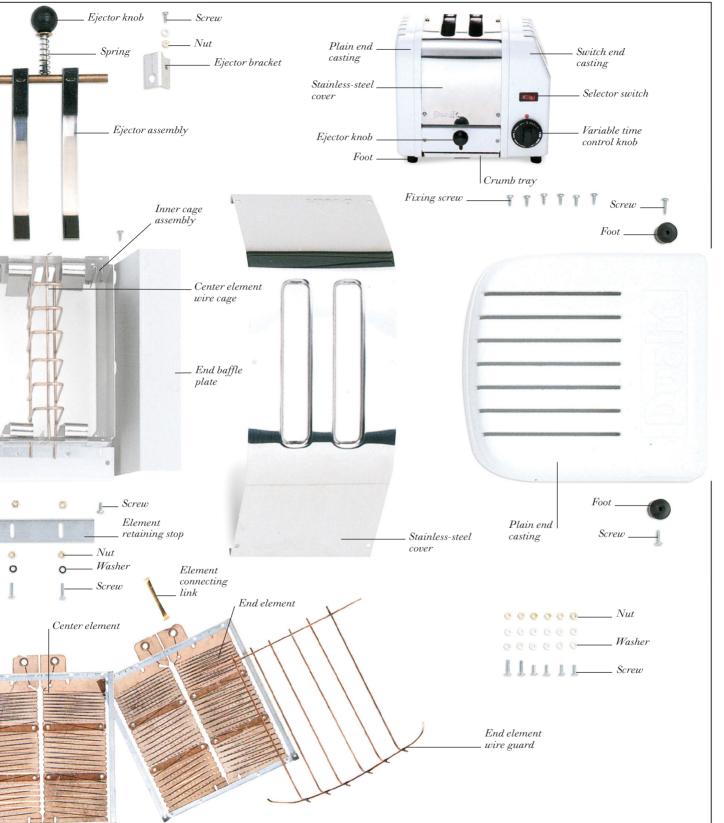
SIDE VIEW OF MICROWAVE COMBINATION OVEN



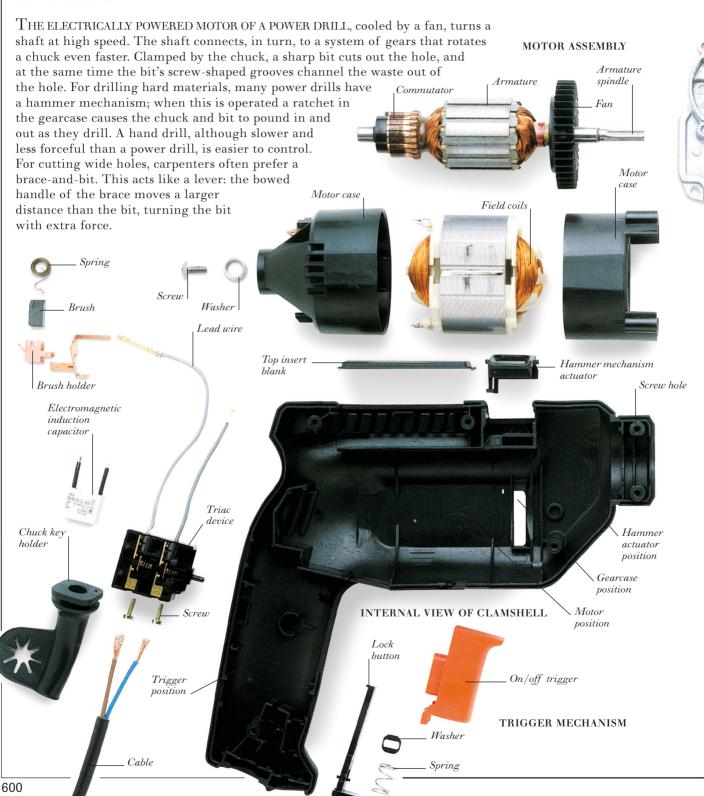


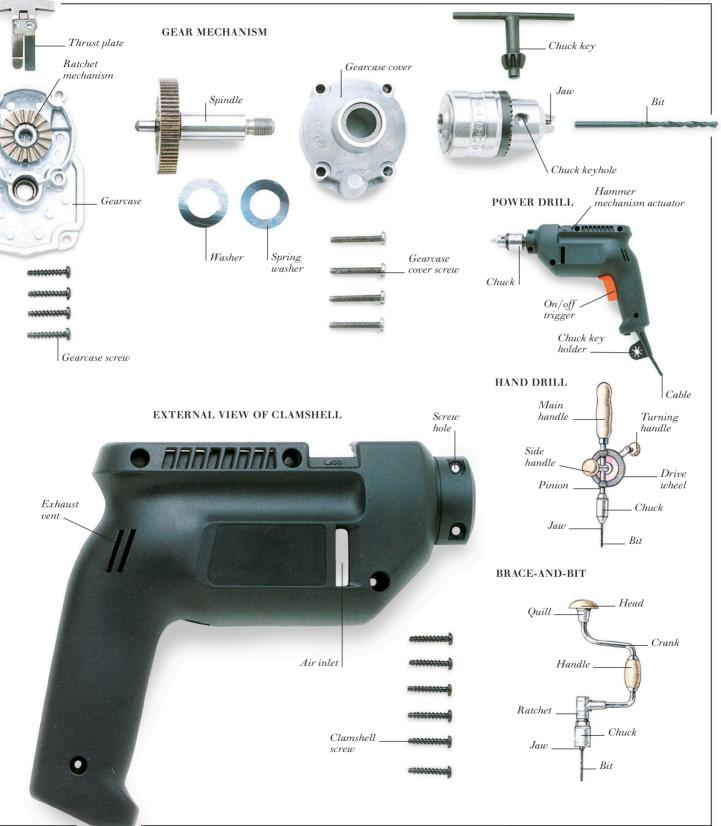






Drills



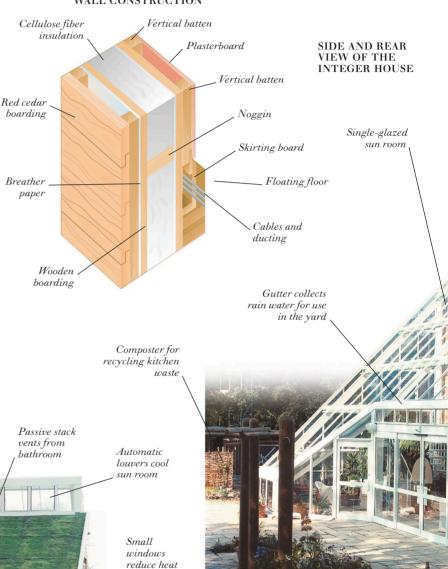


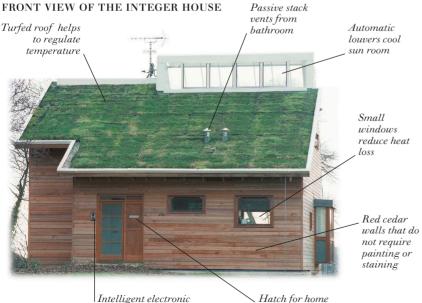
House of the future

Houses in the future are likely to be more environmentally friendly and energy-efficient than older dwellings, by making better use of materials and intelligent control systems. The Integer house was designed by Cole Thompson Associates, Bree Day Partnership, and Paul Hodgkins Associates, and built in conjunction with the Building Research Establishment in the UK. One of its key features is a large sun room that warms one side of the house. Extensive use is made of recycled, natural, and renewable materials and energy. The walls are made from timber and insulated with fiber from recycled newspaper; waste water from the bathrooms is saved and used to flush the toilets; and a wind turbine and solar panels contribute some of the electricity requirements. Many elements were prefabricated off-site for ease of construction. The Integer house uses only half the energy and a third less water than a traditionally built house.

door-lock

WALL CONSTRUCTION



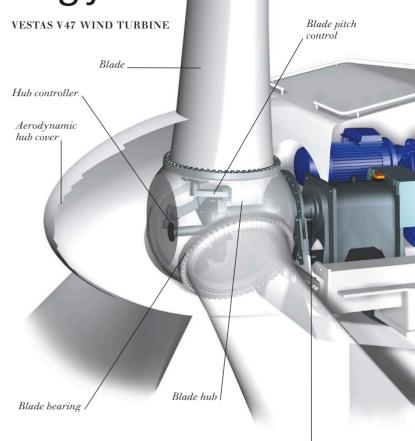


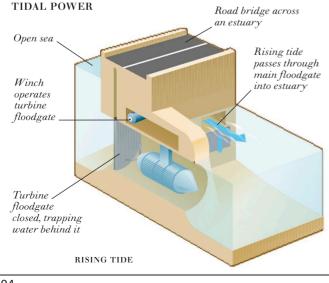
deliveries

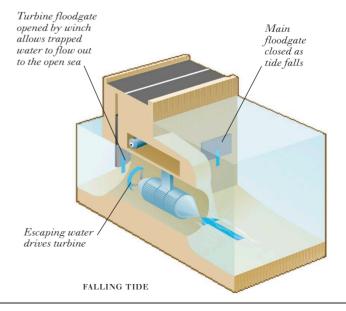


Renewable energy

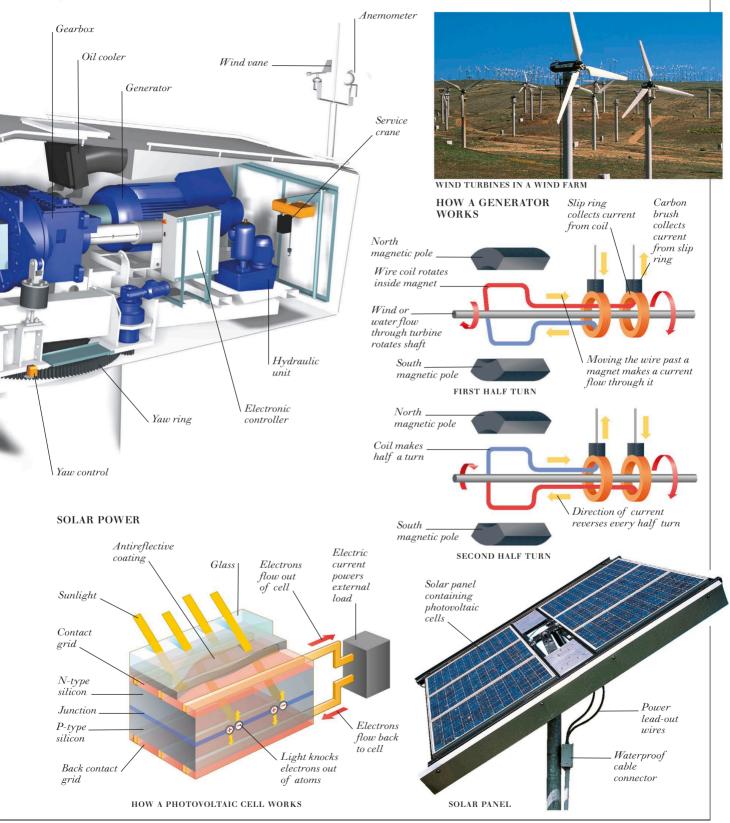
RENEWABLE ENERGY COMES from sources that VESTAS V47 WIND TURBINE do not become depleted as we use the energy. When a fossil fuel such as coal is burned, it is gone forever, but a renewable source remains available no matter how much is used. The tides, waves, flowing water, sunlight, and the wind are all renewable sources of energy. Wind and water energy are captured by a device called a turbine. The turbine spins and drives an electricity generator. Energy from sunlight, or solar energy, is changed into electricity in two main ways. One uses mirrors to concentrate solar energy and magnify its heating effect which is used to change water into steam to drive turbines. Photovoltaic cells change sunlight directly into electricity. A cell is made from two layers of silicon. One gives out electrons (negative particles) and the other receives them. Sunlight knocks electrons out of atoms where the two layers meet, separating them from the positive particles. The electrons are attracted to one layer of the cell, the positive particles to the other layer. Electrons are naturally attracted to the positive particles, but to come together again, the electrons must flow out of the cell, through an external electric circuit, or load, and back to the other side of the cell, creating a charge. The cell supplies electric current for as long as light keeps falling on it.

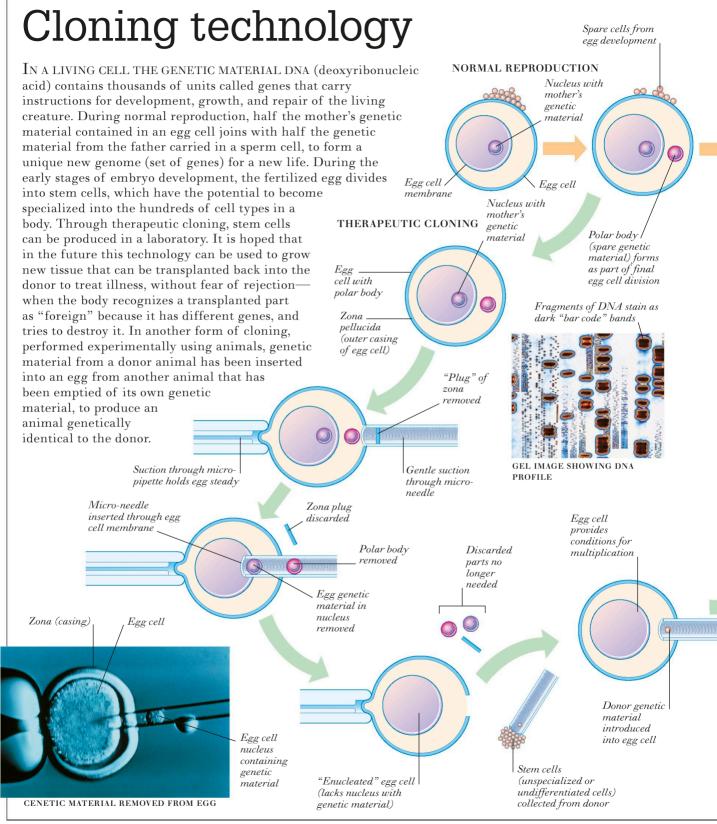


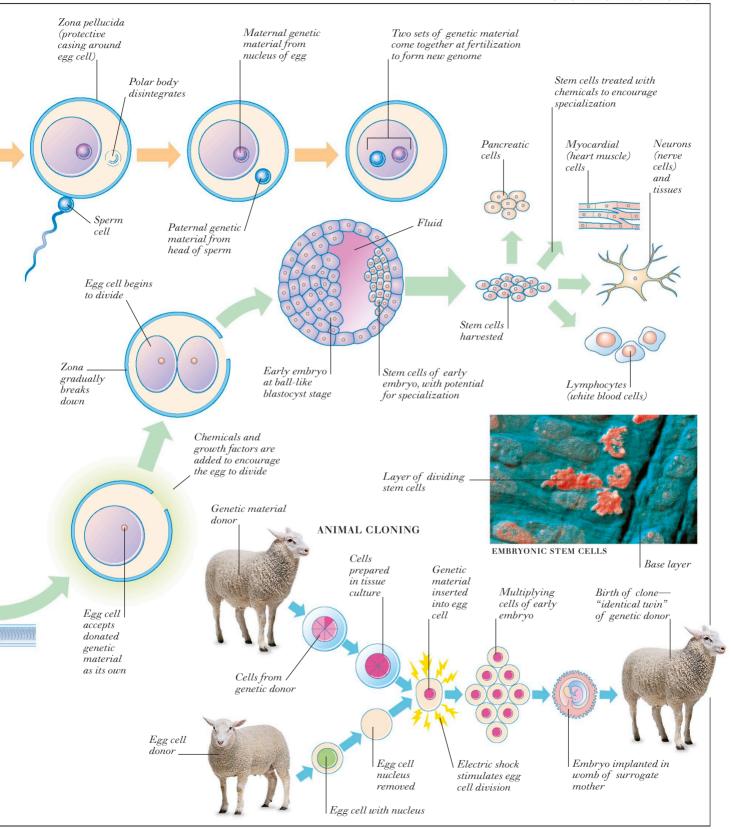


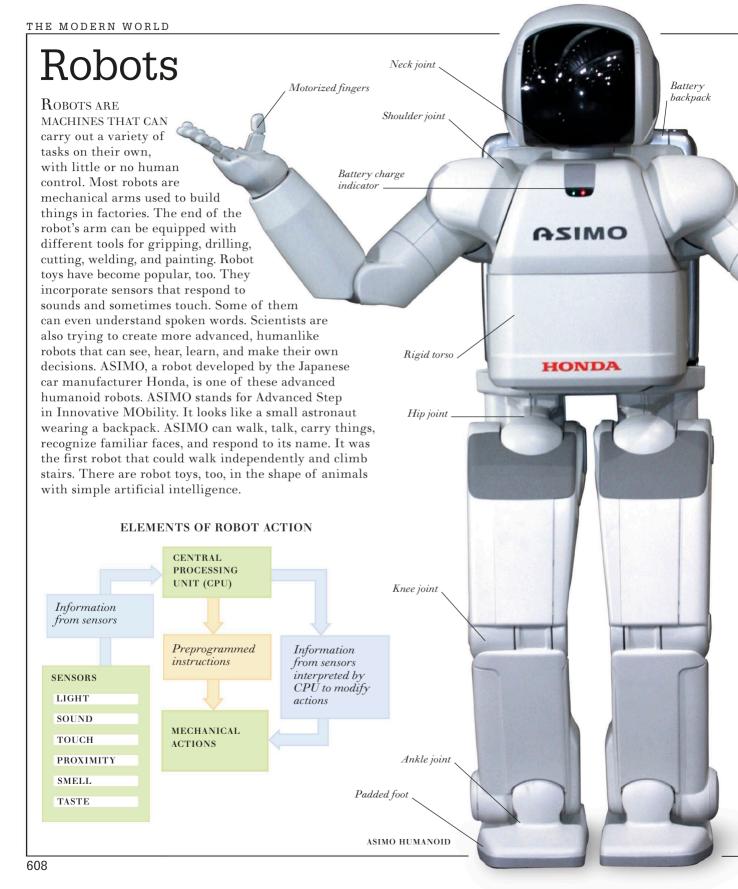


Rotor lock





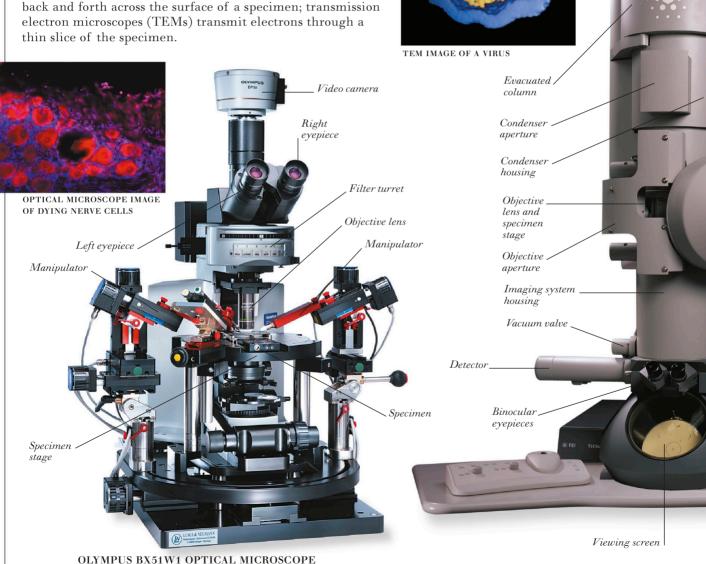






High-performance microscopes

OPTICAL MICROSCOPES FORM A MAGNIFIED image by using lenses to bend light. Some special-purpose optical microscopes used in industry and research are designed for observing particular materials, such as living cells. They produce magnifications of up to about 2,000. Electron microscopes produce magnifications of as much as 50 million, although 2 million is more typical. Their images are formed by means of electrons focused by magnetic lenses. There are two main types: scanning electron microscopes (SEMs) scan electrons back and forth across the surface of a specimen; transmission electron microscopes (TEMs) transmit electrons through a thin slice of the specimen.



FEI TECNAI G² TRANSMISSION ELECTRON MICROSCOPE

Electron

housing



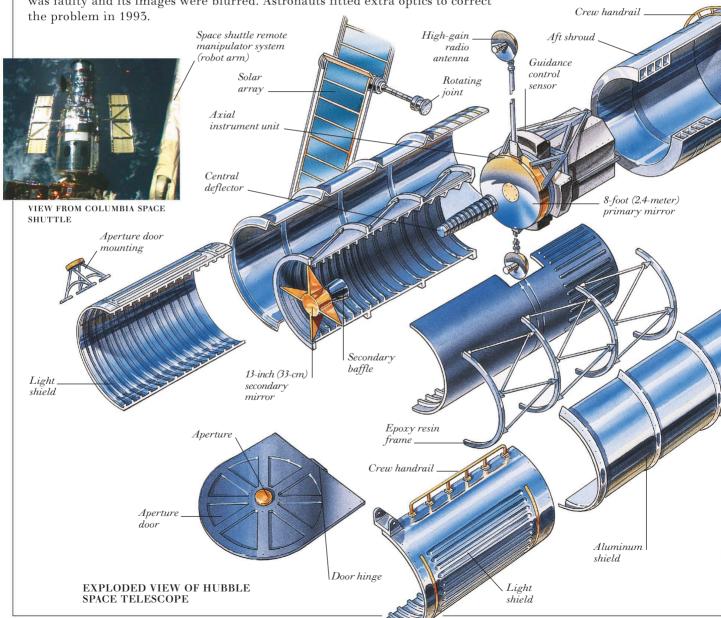
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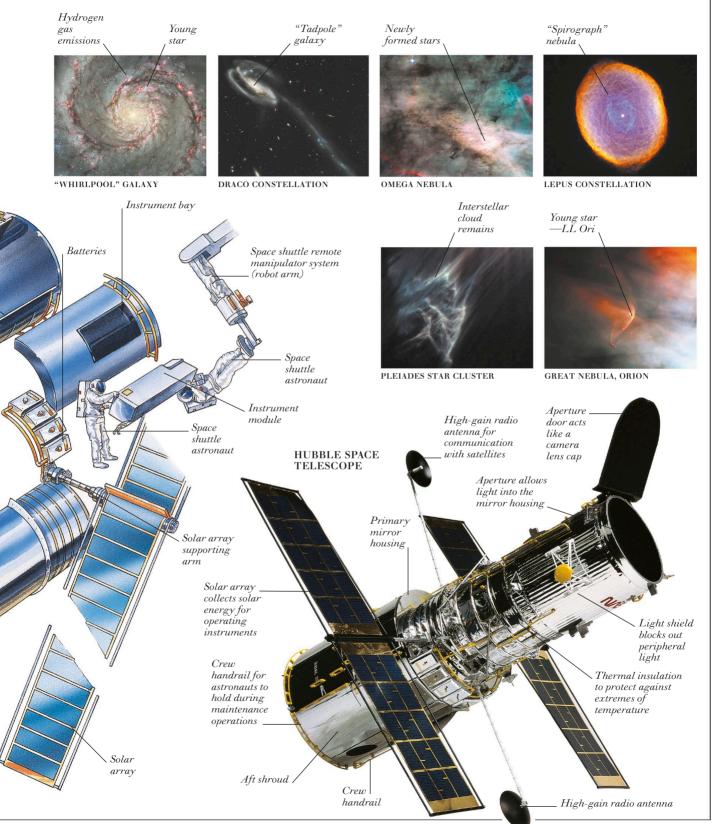
Space telescope

SPACE TELESCOPES ORBIT THE EARTH hundreds of miles above the ground, their instruments collecting light from stars and galaxies. Telescopes in space have a clearer view than those on Earth, because they are unaffected by the Earth's atmosphere, which absorbs or distorts much of this radiation. There are a variety of types of space telescope designed to observe different types of light. The Hubble Space Telescope observes infrared, ultraviolet, and visible light. It can detect objects that are 100 times fainter than those any telescopes on Earth can see. When this 12-ton (11,000-kilogram), 43-foot (13-meter) long telescope was launched by the Space Shuttle in 1990, it was found that its primary mirror was faulty and its images were blurred. Astronauts fitted extra optics to correct the problem in 1993.



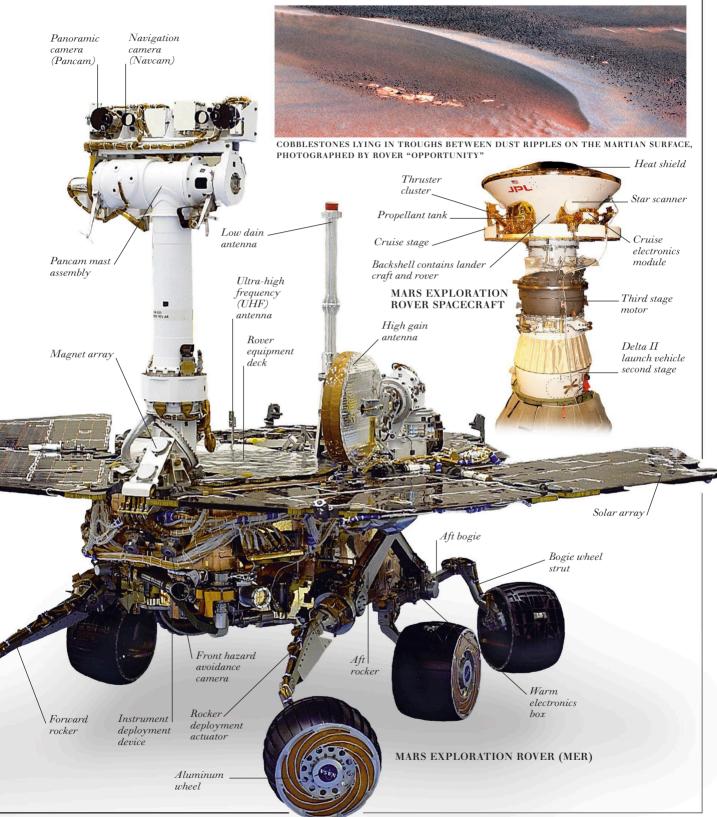
CONE NEBULA





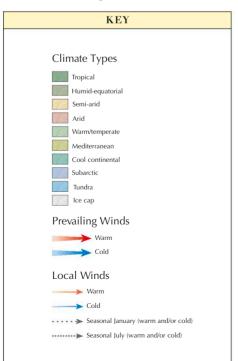
Probing the solar system

SPACE PROBES HAVE VISITED every planet in the solar system. They take photographs and gather data that cannot be collected using Earth-based equipment. Some probes fly past or orbit around planets or moons, while others land. Two Voyager space probes flew past the outer planets in the 1970s and 1980s. Two Viking spacecraft landed on Mars in 1976. The Magellan spacecraft orbited Venus from 1989 and A MAP OF JUPITER'S VAST MAGNETIC FIELD DIONE, ONE OF SATURN'S MOONS. ORBITING ABOVE THE "A" RING PRODUCED BY CASSINI'S INSTRUMENTS mapped its surface. The Pathfinder spacecraft landed on Mars in 1997 and released a rover vehicle Helium Thruster to explore the surface. The tank Mars Exploration Rover (MER) Radio Mission landed two rovers in antenna 2003. The Cassini space probe reached Saturn in 2004, and in Plutonium 2005 its mini-probe, Huygens, power supply landed on one of its moons, Titan, and became the first probe to land on a moon Main engine of another planet. Cosmic dust analyser Sun sensor Experiment platform Radio antenna Fuel for Radio dish thrusters spectrometer Huygens mini probe CASSINI SPACE PROBE AND HUYGENS MINI-PROBE PANORAMIC VIEW OF TITAN THE ROCK-STREWN SURFACE OF TITAN, TAKEN AS HUYGENS DESCENDED PHOTOGRAPHED BY HUYGENS

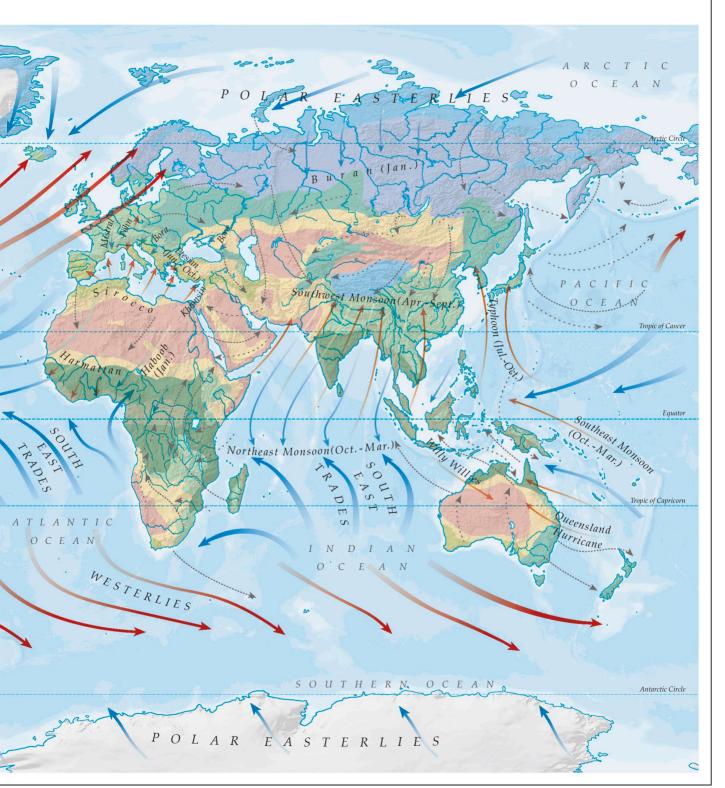


Climate map of the world

This map depicts climate zones across the world. Climate refers to the prevailing weather conditions of an area over a long period of time, and it is affected by various factors. A crucial factor is the distance of an area from the equator, with places further away from it being much colder. This is due to the curvature of the Earth. which means that the sun's rays are dispersed over a larger area. As this map shows, prevailing winds also affect the climate of a place. Oceans play a critical role in determining climate. Areas that are above sea level are cooler, as air at higher altitudes is less dense and therefore unable to hold heat as well. As well as this, places closer to the coast tend to be more temperate, as oceans heat up and cool down more slowly than land, regulating land temperature. Ocean currents also influence climate type. Due to varying weather conditions, each climate has a distinctive range of flora and fauna.







Time zones

The world is divided into 24 time zones, measured in relation to 12 noon Coordinated Universal Time (UTC), on the Greenwich Meridian (0°). Time advances by one hour for every 15° longitude east of Greenwich (and goes back one hour for every 15° west), but the system is adjusted in line with administrative boundaries. Numbers on the map indicate the number of hours that must be added to, or subtracted from UTC to calculate the time in each zone. Thus, the eastern United States (–5) is 5 hours behind UTC.

TYPES OF CALENDAR

GREGORIAN

The 365-day Gregorian calendar was introduced by Pope Gregory XIII in 1582 and is now in use throughout most of the Western world. Every four years (leap year) an extra day is added. Below are the names of the months (and number of days).

January (31)	July (31)
February (28, 29 in	August (31)
leap years)	September (30)
March (31)	October (31)
April (30)	November (30)
May (31)	December (31)
June (30)	` ′

JEWISH

The Jewish calendar is a lunar calendar adapted to the solar year. It normally has 12 months but in leap years, which occur seven times in every cycle of 19 years, there are 13 months. The years are calculated from the Creation (which is placed at 3761 BC); the months are Nisan, Iyyar, Sivan, Thammuz, Ab, Elul, Tishri, Hesvan, Kislev, Tebet, Sebat, and Adar, with an intercalary month (First Adar) being added in leap years.

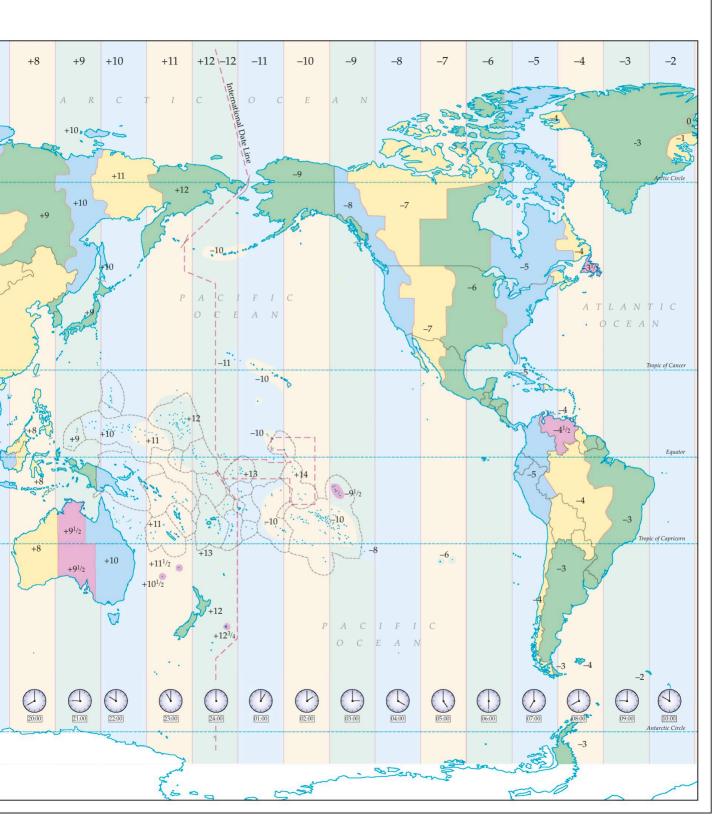
ISLAMIC

The Islamic calendar is based on a year of 12 months, each month beginning roughly at the time of the New Moon. The months are Muharram, Safar, Rabi'II, Rabi'II, Jumada I, Jumada II, Rajab, Sha'ban, Ramadan, Shawwal, Dhu l-Qa'dah, and Dhu l-Hijja.

CHINESE

The Chinese calendar is a lunar calendar, with a year consisting of 12 months. Intercalary months are added to keep the calendar in step with the solar year of 365 days. Months are referred to by a number within a year, but also by animal names that, from ancient times, have been attached to years and hours of the day.





Useful data

UNITS OF MEASUREMENT

UNITS OF MEASUREMENT		
METRIC UNIT	EQUIVALENT	
Length 1 centimeter (cm) 1 meter (m) 1 kilometer (km)	10 millimeters (mm) 100 centimeters 1,000 meters	
Mass 1 kilogram (kg) 1 metric ton (t)	1,000 grams (g) 1,000 kilograms	
Area 1 square centimete (cm²) 1 square meter (m² 1 hectare 1 square kilometer (km²)	(mm^2) $^2)$ 10,000 square centimeters 10,000 square meters	
Volume 1 cubic centimeter 1 liter (l) 1 cubic meter (m ⁵)	1,000 milliliters	
Capacity (liquid 1 centiliter (cl) 1 deciliter (dl) 1 liter (l) 1 decaliter (dal) 1 hectoliter (hi) 1 kiloliter (kl)	and dry measures) 10 milliliters (ml) 10 centiliters 10 deciliters 10 liters 10 decaliters 10 decaliters	

IMPERIAL UNIT	EQUIVALENT	ROMAN	ARABIC
Length		I	1
1 foot (ft)	12 inches (in)	II	2
1 yard (yd)	3 feet	III	3
1 rod (rd)	5½ yards	IV	4
1 mile (mi)	1,760 yards	V	5
, ,		VI	6
Mass		VII	7
1 dram (dr)	27.344 grains (gr)	VIII	8
1 ounce (oz)	16 drams	IX	9
1 pound (lb)	16 ounces	X	10
1 hundredweight (cwt)	112 pounds	XI	11
(long)		XII	12
1 hundredweight (cwt)	100 pounds	XIII	13
(short)		XIV	14
1 ton (long)	2,240 pounds	XV	15
1 ton (short)	2,000 pounds	XX	20
		XXI	21
Area		XXX	30
1 square foot (ft²)	144 square inches	XL	40
(in^2)	1 square yard (yd²)	L	50
9 square feet		LX	60
1 acre	4,840 square yards	LXX	70
1 square mile	640 acres	LXXX	80
37. 3		XC	90
Volume	4.700 1: : 1	C	100
1 cubic foot	1,728 cubic inches	CI	101
1 cubic yard	27 cubic feet	CC	200
0 : 0: 11		CCC	300
Capacity (liquid and d		CD	400
1 fluidram (fl dr)	60 minims (min)	D	500
1 fluid ounce (fl oz)	8 fluidrams	DC	600
1 gill (gi)	5 fluid ounces	DCC	700
1 pint (pt)	4 gills	DCCC	800
1 quart (qt)	2 pints	CM	900
1 gallon (gal)	4 quarts	M	1,000
1 peck (pk)	2 gallons	MM	2,000
1 bushel (bu)	4 pecks		

NUMBER SYSTEMS

TO CONVERT	INTO	MULTIPLY BY
Length		
Centimeters	inches	0.3937
Meters	feet	3.2810
Kilometers	miles	0.6214
Meters	yards	1.0940
Mass		
Grams	ounces	0.0352
Kilograms	pounds	2.2050
Metric tons	long tons	0.9843
Metric tons	short tons	1.1025
Area		
Square centimeters	square inches	0.1550
Square meters	square feet	10.7600
Hectares	acres	2.4710
Square kilometers	square miles	0.3861
Square meters	square yards	1.1960
Volume		
Cubic centimeters	cubic inches	0.0610
Cubic meters	cubic feet	35.3100
Capacity		
Liters	pints	1.7600
Liters	gallons	0.2200

IMPERIAL TO METRIC CONVERSIONS

TO CONVERT	INTO	MULTIPLY BY
Length		
Inches	centimeters	2.5400
Feet	meters	0.3048
Miles	kilometers	1.6090
Yards	meters	0.9144
Mass		
Ounces	grams	28.3500
Pounds	kilograms	0.4536
Long tons	metric tons	1.0160
Short tons	metric tons	0.9070
Area		
Square inches	square centimeters	6.4520
Square feet	square meters	0.0929
Acres	hectares	0.4047
Square miles	square kilometers	2.5900
Square yards	square meters	0.8361
Volume		
Cubic inches	cubic centimeters	16.3900
Cubic feet	cubic meters	0.0283
0 '		
Capacity	12.	0.5697
Pints	liters	0.5683
Gallons	liters	4.5460

RULES OF ALGEBRA

EXPRESSION	COMMENTS	EXPRESSION BECOMES
a + a $a + b = c + d$	Simple addition Subtract b from either side	2a $a = c + d - b$
ab = cd (a + b) (c + d)	Divide both sides by b Multiplication of bracketed terms	$a = cd \div b$ $ac + ad + be + bd$
$a^{2} + ab$ $(a + b)^{2}$	Use parentheses Expand terms in parentheses	a(a + b) $a^2 + 2ab + b^2$
\hat{a}^2 — \hat{b}^2	Difference of two squares	(a+b)(a-b)
$\frac{1/a + 1/b}{a/b \div c/d}$	Find common denominator Dividing by a fraction is the same as multiplying by its reciprocal	(a + b)/ab $a/b \times d/c$

POWERS OF TEN USED WITH SCIENTIFIC UNITS

FACTOR	NAME	PREFIX	SYMBOL
1018	quintillion	exa-	E
10^{15}	quadrillion	peta-	P
10^{12}	trillion	tera-	T
10^{9}	billion	giga-	G
10^{6}	million	mega-	M
10^{3}	thousand	kilo-	k
10^{2}	hundred	hecto-	h
10^{1}	ten	deca-	da
10-1	one-tenth	deci-	d
10^{-2}	one-hundredth	centi-	С
10-3	one-thousandth	milli-	m
10^{-6}	one-millionth	micro-	u
10-9	one-billionth	nano-	n
10^{-12}	one-trillionth	pico-	p
10^{-15}	one-quadrillionth	femto-	p f
10-18	one-quintillionth	atto-	a

Note: The American system of numeration for denominations above one million is used in this book. In this system, each of the denominations above one billion (1,000 millions) is 1,000 times the preceding one.

BIOLOGY SYMBOLS

SYMBOL	MEANING
0	female individual
	(used in inheritance charts) male individual
♀ ♂ ×	(used in inheritance charts) female male
× +	crossed with; hybrid wild type
$\mathbf{F_1}$	offspring of the first
\mathbf{F}_2	generation offspring of the second generation

TEMPERATURE SCALES

To convert from Fahrenheit (F) to Celsius (C): C = (F—32) \times 5 \div 9 To convert from Celsius to Fahrenheit: F = (C \times 9 \div 5) + 32

To convert from Celsius to Kelvin (K): $K = \hat{C} + 273$

To convert from Kelvin to Celsius: C = K - 273

Celsius -10 0 10 20 30 50 60 70 80 90 100 Fahrenheit -4 86 176 194 212 14 32 50 68 104 122 140 158 253 363 Kelvin 263 273 283 293 305 313 325 333 343 353 373

| MATHEMATICAL SYMBOLS

SYMBOL	EXPLANATION
+	addition
-	subtraction
×	multiplication
÷	division
=	equals
\neq	does not equal
>	greater than
<	less than
X	greater than or equal to
\leq	less than or equal to
∞	infinity
%	percent
π	pi (3.1416)
0	degree
\approx	is approximately equal to
≅ Z Π Σ	angle
Π	parallel to
Σ	summation
u, u	vectors
f(x)	function
! √ ξ A ∩ B	factorial
√ 	square root
ξ	universal set
$A \cap B$	intersection
$A \cup B$	unison
$A \subset B$	subset
Ø	null set
-	

CHEMISTRY SYMBOLS

CHEMISTRI STMBOLS		
SYMBOL	MEANING	
+	plus; together with	
_	single bond	
•	single bond; single	
	unpaired electron; two	
	separate parts or	
	compounds regarded	
	as loosely joined	
=	double bond	
=	triple bond	
R	group	
\mathbf{X}	halogen atom	
\mathbf{Z}	atomic number	

SCIENTIFIC NOTATION

PHYSICS SYMBOLS

MEANING

wavelength micro-; permeability

conductivity

velocity of light

electronic charge

beta ray

alpha particle

gamma ray; photon

electromotive force

efficiency; viscosity

frequency; neutrino density; resistivity

SYMBOL

 $_{\beta}^{\alpha}$

ε

η

μν

ρ

σ

 \mathbf{c}

NUMBER	NUMBER BETWEEN 1 AND 10	POWER OF TEN	SCIENTIFIC NOTATION
10	1	101	1 3 10 ¹
150	1.5	$10^2 (= 100)$	$1.5 \ 3 \ 10^{2}$
274,000,000	2.74	$10^8 (= 100,000,000)$	$2.74\ 3\ 10^{8}$
0.0023	2.3	$10^{-5} (= 0.001)$	$2.3\ 3\ 10^{-3}$

TRIGONOMETRY

Angle A (degrees)	sin A	cos A	tan A
0	0	1	0
30	1/2	$\sqrt{3}/2$	1/√3
30 45	$1/\sqrt{2}$	1/√2	1
60	√3/2	1/2	√ 3
90	1	0	00

Shapes: Plane

Two-dimensional shapes are termed plane (or flat) shapes. Plane shapes constructed with straight sides, as illustrated here, are called polygons. They are categorized according to the number of sides they have—for example, three-sided polygons are known as triangles. A polygon that has sides of

equal length and internal angles of equal size, such as a square,

is said to be regular.



SCALENE TRIANGLE A triangle (three-sided polygon) with no equal sides or angles.



ISOSCELES TRIANGLE A triangle with only two sides and two angles equal.



RIGHT-ANGLED TRIANGLE A triangle with one angle as a right angle (90°).



EQUILATERAL TRIANGLE A regular triangle. All angles are 60°.



SQUARE A regular quadrilateral. All angles are 90°.



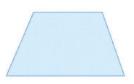
RHOMBUS A quadrilateral with all sides equal and two pairs of equal angles.



RECTANGLE A quadrilateral with four right angles and opposite sides of equal length.



PARALLELOGRAM A quadrilateral with two pairs of parallel sides.



TRAPEZIUM A quadrilateral with one pair of parallel sides.



PENTAGON A five-sided polygon. A regular pentagon is shown above.



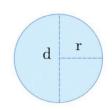
HEXAGON A six-sided polygon. A regular hexagon is shown above.



OCTAGON An eight-sided polygon. A regular octagon is shown above.

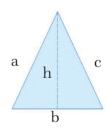
AREAS AND PERIMETERS

The formulae for calculating the areas and perimeters of simple plane shapes were devised by Classical Greek mathematicians



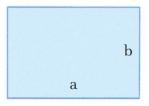
CIRCLE r = radius $d = diameter = 2 \times r$

Circumference = $2 \times \pi \times r$ Area = $\pi \times r^2$ $(\pi = 3.1416)$



TRIANGLE Height = hSides = a, b, c

Perimeter $\equiv a + b + c$ Area $\equiv \frac{1}{2} \times b \times h$



RECTANGLE Sides = a, b

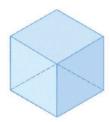
Perimeter = $2 \times (a + b)$ $Area = a \times b$

Shapes: Solid

Three-dimensional shapes are known as solid shapes and include spheres, cubes, and pyramids. A solid shape with a polygon at each face is called a polyhedron.



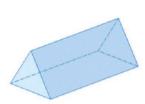
TETRAHEDRON A four-sided polyhedron. A regular tetrahedron is shown.



CUBE
A regular hexahedron.
All sides are equal and
all angles are 90°.



OCTAHEDRON A polyhedron with eight sides.



PRISM
A polyhedron of constant cross-sections in planes perpendicular to its longitudinal axis.



PYRAMID
A polygonal base and triangular sides that meet at a point.



 $\begin{array}{c} {\bf TORUS} \\ {\bf A\ doughnutlike,\ ring\ shape.} \end{array}$



SPHERE
A round shape, as in a ball or an orange.



HEMISPHERE
Formed when a sphere is cut exactly in half.



SPHEROID

An egg-shaped solid object whose cross-section is a circle or an ellipse.



CONE
An elliptical or circular base with sides tapering to a single point.



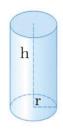
RIGHT CYLINDER
A tube-shaped, solid
figure. A right cylinder has
parallel faces.



HELIX
A twisted curve. The distance moved in one revolution is its pitch.

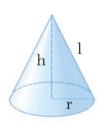
SURFACE AREAS AND VOLUMES

Volume refers to the amount of space that a solid object occupies. Its surface area is the sum of the area of each of its faces.



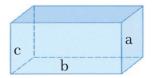
CYLINDER
Surface area = $2 \times \pi \times r \times h + 2\pi r^2$ Volume = $\pi \times r^2 \times h$

Height = hRadius = r



 $\begin{aligned} & \text{CONE} \\ & \text{Surface area} = \\ & \pi \times r \times l + \pi r^2 \\ & \text{Volume} = \frac{1}{3} \times \pi \times r^2 \times l \end{aligned}$

Height = h Radius = r Side = l



 $\begin{aligned} & \textbf{RECTANGULAR BLOCK} \\ & \textbf{Surface area} = \\ 2 \left(a \times b + b \times c + a \times c \right) \\ & \textbf{Volume} = a \times b \times c \end{aligned}$

 $Sides \equiv a,\,b,\,c$

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